SIZE, AGE STRUCTURE AND DIET PREFERENCES OF AN INVASIVE POPULATION OF REDBREAST SUNFISH (*LEPOMIS AURITUS*) IN RICHLAND CREEK, HAYWOOD COUNTY, NORTH CAROLINA.

A thesis presented to the faculty of the Graduate School of Western Carolina University in partial fulfillment of the requirements for the degree of Masters of Science in Biology

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SIZE, AGE STRUCTURE AND DIET PREFERENCES OF AN INVASIVE POPULATION OF SUNFISH (*LEPOMIS AURITUS*) IN RICHLAND CREEK, HAYWOOD COUNTY, NORTH CAROLINA.

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In Richland Creek, Haywood County, North Carolina, the invasive species, Redbreast Sunfish, *Lepomis auritus* (Linnaeus 1758), dominates the fish assemblage. As part of a study of the feasibility of using backpack electrofishing to selectively remove the invasive, Redbreast Sunfish were removed from three reaches of Richland Creek. The sacrificed fish were used to gain insight into the population characteristics of this population. Data on total length, wet weight and age, were recorded. Stomach contents were identified to the lowest taxon feasible, and compared to standardized invertebrate samples collected near the time of fish sampling. Fish sacrificed ranged from total lengths of 31 mm to 168 mm. Fish were found from zero to three years old, with the majority of fish being in their first or second year of life. The fish collected in sites close to a small reservoir downstream were smaller than fish collected upstream, indicating that the river population was likely a sink population to the reservoir. This population of Redbreast Sunfish ate a variety of invertebrates, as well as a fish, supporting our hypothesis that they, as many invasive species, are generalists. They showed a slight preference for chironomids, and appeared to avoid mayflies.

INTRODUCTION

Invasive Species

The impact of invasive species on natural ecosystems has been an important theme in ecological research for several decades. The addition of a new species to an ecosystem can change the dynamics of the ecosystem as a whole, as well as alter the behaviors, diets, growth rates and survival of other species (Brown & Moyle 1997, Fisher Huckins et al. 2000, Lepori et al. 2012, Mills et al. 1994 and Moyle et al. 2003). Many populations of native species have been negatively affected by invasive species (Ludyanskiy et al. 1993). Non-native species have been shown to reduce species diversity or even result in the extinction of endemic populations (Folkerts 1997). These negative effects are often due to, but not limited to, competition for limited resources, habitat changes, hybridization and/or diseases brought into the system (Gozlan et al. 2010, Orwig et al. 2002). Invasive species do not necessarily have to be from different continents to be hazardous to an ecosystem; even fish from nearby watersheds have been found to have a negative effect on natural populations (Fisher Huckins et al. 2000).

Invasive species can be introduced via anthropogenic actions, disturbances or shifts in ecosystem dynamics (Folkerts 1997). Any disturbance may alter an ecosystem. Often, alteration allows non-native species to invade and take over areas previously inhabited by native species (Shea & Chesson 2002). Often, invasive species have characteristics that allow them to survive in disturbed ecosystems, such as an area of high pollution (Carrithers & Bulow 1973). Non-native species are often the first to colonize disturbed areas, with the native species entering gradually as the system becomes more stable (Wildish & Thomas 1985). Invasive species often show hightrait plasticity (Vila-Gispert et al. 2005) and tolerance to variation in environmental

temperature, salinity and water quality (Rahel & Olden 2008). Successful invasive fish species usually exhibit generalist food habits (Harms & Turingan 2012). Vila-Gispert et al. (2005) found most exotic fish species to be characterized by larger size, longer longevity, late maturity, high fecundity, fewer spawning per year and a shorter reproductive span than native fish.

Non-native species have a negative effect on populations of similar trophic levels, as well as on shared prey items (Liao et al. 2002). Prey availability, as well as composition, is an important factor in ecosystem dynamics (Sammons and Macenia 2006). The niches of coexisting species are often altered by disturbance, shifting the system from a stable state toward more negative interactions among species, often with the invasive species out-competing or altering the diet preferences of native species (Fisher Huckins et al. 2000). In the presence of non-native competitors, body condition of native species has been shown to be consistently below average due to decreases in prey and habitat availability (Neal et al. 2001).

Restoration of Aquatic Ecosystems

Freshwater systems are sensitive to the effects of invasive species due to the semi-discrete nature of these ecosystems (Moyle 1986). Freshwater systems are also extremely sensitive to pollution. Runoff from land pollution makes creeks highly susceptible to hazardous waste accumulation, causing a negative impact on native species, which opens niches for non-native fish to dominate the ecosystem. Because of the intensive monitoring and recording of fish stocking in streams and lakes, these ecosystems are a hotspot for invasive species research (Fisher Huckins et al. 2000).

As in many ecosystems, the amount of prey in streams is limited, so resource partitioning among coexisting populations is important (Raborn et al. 2004). Native flora, invertebrates, mollusks, fish and amphibians may all be affected by the introduction of non-native species

(Dodd, Jr. 1997). Werner and Hall (1977) studied two species of sunfish and found the less dominant species shifted its foraging from between submersed macrophytes to the open water column, resulting in a change in diet. Fisher Huckins et al. (2000) also noted that pumpkinseed sunfish, *L. gibbosus* (Linnaeus 1758), diets shifted dramatically from amphipods and chironomid larvae to snails in the presence of invasive redear sunfish, *L. microlophus* (Günther 1859),

After a disturbance, especially an anthropogenic disturbance such as contamination by hazardous materials or habitat alteration, restoration efforts are often attempted to restore the ecosystem to its best-attainable, or if possible, its pre-disturbance state (Stoddard et al. 2006). Restoration efforts often involve the removal of pollutants, treating the water to improve quality, and, if necessary, restocking previously present populations of native species (NCDENR 2012).

Restocking populations of native fish can be extremely difficult, as biotic and abiotic changes for the disturbance are unavoidable regardless of the amount of effort put into restoration (Scott et al. 2003). Because of the altered state of the ecosystem, the translocated organisms may not develop sustainable populations (Scott et al. 2003). A frequently observed factor influencing the successful reintroduction of populations is the presence of non-native species (Scott et al. 2003). These non-native species could be tolerant species capable of colonizing areas with low water quality, or they could be quick colonizers, moving in when the native species were extirpated. Therefore, for these native species to survive, the invasive populations must be removed. This has proved to be a successful conservation tool for ecosystems suffering from negative impacts due to invasive species (Carmona-Catot et al. 2010).

Redbreast Sunfish

The Redbreast Sunfish, *Lepomis auritus* (Linnaeus 1758), is a popular game fish in eastern United States (Etnier and Starnes 1993). Their preferred habitat is the main channel of

streams and rivers (Etnier and Starnes 1993). In North Carolina, they are native to Atlantic and Gulf drainages (Burr and Page 1986), but have been introduced into other drainages, including the French Broad-Holston drainage (Menhinick 1991), including Richland Creek. They reach maturity at about two years of age, and have been recorded as large are 900 grams (Etnier and Starnes 1993). Their diet consists of mainly of aquatic macroinvertebrates (Davis 1972).

Objectives

Richland Creek in Haywood County has a persistent population of invasive Redbreast Sunfish, which may be affecting native fish species. Miranda Aiken analyzed the feasibility of eliminating the Redbreast Sunfish population through selective removal by electroshocking. I used the fish that were removed to describe the age, size and sex structure of the invasive population in Richland Creek, as well as their diet composition in order to better understand how they may affect recovery of native fish, such as Rock Bass (*Ambloplites rupestris*) (Rafinesque 1871), in this stream.

METHODS

Study Site

Richland Creek flows in a generally northeastern direction from its headwaters near the boundary between Haywood and Jackson Counties, NC, through Waynesville, NC, to its mouth on the Pigeon River (35.549799^{0}N, 82.946653^{0}W) approximately 10 km downstream of Canton, NC. Richland Creek was dammed in 1913 approximately 4 km upstream from its mouth, creating 81 ha Lake Junaluska. The Richland Creek watershed encompasses an area of approximately 17,700 ha and while the headwaters drain mostly protected forestland, the main stem flows through the most heavily developed portion of Haywood County.

Barber's Orchard in Haywood County, North Carolina was declared an EPA superfund site in 1999, due to high levels of arsenic, lead, and pesticides (EPA 2012a). Richland Creek drains this site, and the aquatic life in the stream has been affected by the pollution from Barber's Orchard (Miller et al. 2005). In addition, local agriculture and septic straight piping produced high levels of fecal coliform bacteria in the creek. In 1964, Messer found high densities of dipterans, indicating poor water quality due to large quantities of raw sewage and agriculture runoff. This excess of bacteria along with increased sedimentation led to low biotic integrity and in 2002, 15 miles of Richland Creek were listed as impaired under Section 303d of the Clean Water Act (EPA 2012b). Restoration work is currently being done, including successful efforts to improve water quality, and reintroduction of native fish species such as Rock Bass (*A. rupestris*), Warpaint Shiners (*Luxilus coccogenis*) (Cope1868), and River Chubs (*Nocomis micropogon*) (Cope 1865), has been attempted with varying success (NCDENR 2012). North Carolina Department and Environment and Natural Resources (NCDENR) has been monitoring the creek since it was

listed in 2002. The total number of fish caught has increased from 116 in 2002 to 224 in 2007, and the North Carolina Index for Biological Integrity (NCBI score) increased from 30 (poor) in 2002 to 40 (good-fair) in 2007 (EPA 2012b).

Despite this improvement, many native species of fish are not maintaining sustainable populations, which was addressed in unpublished meeting notes of the NC Pigeon River Steering Committee (21 February 2013). Although only two Redbreast Sunfish were found when the creek was surveyed in 1964 (Messer), this species has invaded Richland Creek and has persisted through the years (NCDENR 2014). Miranda Aiken conducted a feasibility study of removing the Redbreast Sunfish from three reaches Richland Creek.

Sample Collection

Study sites (Figure 1) were selected based on ease of electrofishing accessibility, known *L. auritus* distribution, and suggestions from North Carolina Wildlife Resource Commission and North Carolina Department of Environment and Natural Resources (Aiken 2014). Sites were designated A, B, and C, and were each 100 meters long.

Site A (35.515627, - 82.969819) was the site farthest downstream, located just upstream of Lake Junaluska and adjacent to the Waynesville Greenway. This reach stretched under two overpasses of Highway 23/74, and received occasional direct runoff from the road. Canopy cover of this reach was 60%, wetted width was 13.2 m, and depth ranged 0-1 m. There were riffles, pools, and runs. This reach was lined with riparian forest, with a golf course beyond a five meter wide riparian zone on one side of the creek, and four-lane paved road past the riparian zone on the other side. We also sampled about five meters of Raccoon Creek, a tributary that intersects Richland Creek.

Site B (35.511579, - 82.974559) was located adjacent to the Evergreen Paper Company packaging plant and the Waynesville Walking Trail off Howell Mill Road. Canopy cover was 40%, wetted width was 12 meters, and depth ranged 0.5-1.0 m. One side of the creek was lined with dense riparian forest, while the other side was lined by a riparian zone less than 10 meters wide, followed by a large grassy area. This reach contained riffles, pools, and runs and was swifter and rockier than site A, with large rocks and weedy debris lining the bank.

Site C (35.503932, - 82.976297) was located on the grounds of the Waynesville Recreation Park, off Vance Street. Canopy cover was 75%-80%, wetted width was 12 meters, and the depth ranged from 0.3- 1.0 m. There was a riparian zone, about two meters wide, on each side of the stream, with a concrete walking trail on one side and railroad tracks on the other. This reach contained riffles, pools and runs. This site was similar to site B and was swifter and rockier than site A, with large rocks and woody debris comprising a large proportion of the bank.

Seasonal variations in temperature, as well as other abiotic elements are important factors in diet availability and preference (Windell 1971), so we collected samples of *L. auritus* and benthis macroinvertebrates from each site once per month during the months of September, October, November, March, April, May, and June. Due to extreme cold and/or high water level, we could not collect during the winter months, nor rainy summer months. *L. auritus* were sampled by backpack electrofishing as part of an invasive species removal experiment (Aiken 2014). All *L. auritus* were euthanized by over-dosing with MS-222 following the protocol recommended by the American Fisheries Society (2002). The fish remained immersed in the MS222 solution for 10 minutes after their last observed opercular movements then placed on ice for transport to Western Carolina University. All fish not sacrificed (including non-target

species encountered) were immediately returned to the creek downstream (out of the electrical field).

Sampling of macroinvertebrates was conducted in the survey sites within one week of the time of fish sampling via kick sampling using an aquatic sampling net with 0.5 mm mesh bottom attached with canvas to a 0.30 m wide, D-shaped frame. Visual inspection of substrate was used to sample from "rock" habitat. Invertebrate samples were collected from four habitats at each site – kick sampled from a riffle habitat, a run habitat, and a pool, and picking specimens directly from the bottom of rocks. Invertebrate samples were preserved in 80% ethanol and identified to the lowest taxon feasible using keys in Merritt et al. (2008).

Analysis of Samples

Total length and wet weight of *L. auritus* were recorded to determine size structure of the population. Relative weight was calculated as described by Anderson and Gutreuter (1983). The fish were also examined to determine their sex. The sex of the fish was determined by presence or absence of eggs inside the sacrificed fish. The age of all fish was determined using the scale method (Jearld 1983).

Diet was determined by examination of stomach contents. Individual organisms were sorted and identified to the lowest feasible taxonomic. Composition of diet was calculated using relative frequency, the number of individuals of a certain taxa divided by the total number of individuals found. Relative occurrence was calculated by dividing the number of stomachs each taxa occurred in by the total number of stomachs sampled.

Upon analysis of fall data, I noticed a significant number of oligochaetes in the invertebrate samples, but none were observed in the stomachs. For spring samples, I used a

compound microscope to search for the presence of chaetae to determine the presence of oligochaetes, however the number of individual oligochaetes was impossible to determine.

Statistical Analysis

Comparisons among sites were done using ANOVA and Tukey's pairwise comparison. Prey items in Redbreast Sunfish stomachs and benthic invertebrate samples were compared using Strauss' linear food selection index (1979). This index ranges from 1 to -1, with 0 expected for random feeding, while positive indexes indicate preference of the fish for that diet item, and negative indexes indicate avoidance or inaccessibility of the diet item.

RESULTS

Population Description

A total of 271 *L. auritus* were collected from three sites, over seven months (Appendix B). The length of these fish ranged from 31 mm to 168 mm, with a mean of 78 mm. The wet weight ranged from less than 1 g to 104 g, with a mean of 13 g. The length and weight relationship of the fish that I sampled (Figure 2) was similar to that found by others (Fishbase.org 2014). Most specimens weighed between 0 and 40 g, with only a few larger individuals (Figure 2). Eggs were found in 52 of the 271 fish, indicating that they were female. 95% of these females were 69 mm or longer, this length was used as the minimum length at maturity in an effort to insure that juvenile females were not misidentified as males. 114 fish were this size or larger, and did not have eggs, so were determined to be male (Table 1). Although the population sampled ranged in length from 31 mm to 168 mm, over 70% of the fish fell between 50-100 mm in length, with the frequency of fish on either side tapering off (Figure 3). Ages of fish were determined based on scale annuli. Because of the size bias of electrofishing (Anderson 1995) and subsequent removal of some sizes more than others, only the initial sample was used for age distribution (Figure 4). The length of fish within each age group varies tremendously. Although ages 0+, 1+, and 2+ have different peaks of lengths, they each cover a wide range of lengths. Also note that there are individuals of 0+, 1+, and 2+ in each of the length groups between 80-120 mm (Figure 5).

Seasonal Comparison

There were a few noticeable differences between the population sampled in the fall (September, October, November) compared to the population sampled in the spring (March,

April, May, June). The relative weights, which relate current body condition to expected body condition, were lowest in March, right after winter, followed by a rapid increase to the highest relative weight in May and June (Figure 6). This indicates better body condition in these months, possibly due to the approach of spawning season. The mean length in the fall was 81 mm, while the spring mean length was 70 mm. The fish in the fall were distributed similarly to the length distribution of the total population. The spring fish were skewed more toward smaller fish, and no fish larger than 116 mm (Figure 7).

Site Comparison

Length differed significantly among sites (Table 2) (Figure 8). Site C, the site farthest upstream, had 30% of its population with lengths between 80-89 mm, and a mean of 89. Site A had 28% of its fish falling between 50-59 mm, and had a mean length of 72, which was a significant difference from site C, where the mean length was 17 mm larger, despite site A including the biggest fish caught over the entire year (168mm) (Table 3). Site B, located equidistant distances between sites A and C, has a mean size that was also intermediate, with a mean of 80 mm (Table 3).

Diet

Analysis of the 271 fish collected, yielded 42 specimens with either empty stomachs or no identifiable contents, leaving a total of 229 fish for dietary analysis. In these 229 stomachs, 2527 food items were found. Of these 2527 items, 1161 of them were chironomids, 326 were caddisflies (Trichoptera), and 231 were mayflies (Ephemeroptera) (Appendix C). Chironomids were the most frequently observed diet items at 46%, while other taxonomic groups made up between 0-10% each. Chironomids were also the most frequently occurring diet item among fish, found in 20% of fish inspected. Trichoptera were next most commonly eaten, making up

approximately 13% of the diet and found in 16% of fish sampled. Fish bones and scales were found in one stomach. A few interesting diet items were found with low frequency, including two different kinds of gastropods, crayfish, and isopods (Appendix C).

Seasonal shifts in diet were most noticeable in the number of ephemeroptera, increasing from a relative frequency of 0.02 in the fall to 0.21 in the spring. Other shifts between fall and spring included an increase in chironomids and a decrease in hemipterens.

Diet items were fairly similar when comparing among sites A, B, and C. The most noticeable difference was a higher frequency of Ephemeroptera and Trichoptera and lower frequency of chironomids in site C (Figure 9).

Invertebrates in Environment

Eighty-four benthic macroinvertebrate samples were taken from four habitats at each of the sites, each month sampled. A total of 2311 specimens were identified and sorted into 71 taxonomic groups (Appendix A), and later combined into fewer taxonomic categories for comparison to the diets. The most prominent taxa found in these samples were Ephemerellidae, with a frequency of 19%, with Chironomidae and Hydropsychidae having frequencies of 17% and 16% respectively. Ephemeroptera families Baetidae and Heptageniidae also had high numbers, with 8% and 12% respectively.

Fall and spring had similar frequencies of invertebrates, with the exception of Ephemerellidae. Not a single ephemerellid was found in the fall, but a total of 424 individuals were found in the months of March, April, and May, accounting for 32% of invertebrates sampled in the spring. In the fall, chironimids and hydropsychids had the highest frequencies, with 22% and 23% respectively. The frequency of these two taxa dropped in the spring however, to 9% and 11%, consistent with the appearance of ephemerellids.

Each site had different habitat characteristics (personal observation), which would likely contribute to the different frequencies of invertebrates at each site. Site A had the highest abundance of chironomids, most likely due to the slower water and sandy bottom. Site B had a high number of Hydrophychidae and Site C had a higher prevalence of Ephemerellidae. Most of the other taxa were present in low numbers.

Among habitats, there were high numbers of Ephemerellidae in the run (30%) and pool (28%) habitats, while 29% of invertebrates sampled picked from rocks were Hydropsychidae. The riffle samples were more evenly distributed among a variety of taxa. There were high numbers of Trichoptera on the bottom of rocks, while Ephemerellidae numbers were high in the run habitat.

Diet to Environment Comparison

13 of the 15 invertebrate groups had Strauss index values near zero, indicating that they were eaten in approximately the same proportion as they were encountered. But, two were noticeably different from random. Ephemeroptera were determined to have a Strauss index of -0.3, indicating that it was avoided or unavailable by the fish. Chironomidae had an index of 0.37, indicating a preference by the predator (Figure 10).

DISCUSSION

Population Description

Lattimore and Gibbons (1976) studied four populations of Redbreast Sunfish at the Savannah River Plant near Aiken, South Carolina. They found average total lengths of 107.6 mm, 128.86 mm, and 72.4 mm in thermal canals, and an average total length of 135.56 in a nearby stream. Gautreau and Curry (2012) found a population of special concern in Yoho Lake, New Brunswick, Canada, with an average total length of 125 mm. Compared to these populations in the Redbreast Sunfish's native range, Richland Creek's invasive population is slightly smaller in size. Small fish have been known to take refuge in available habitats, even if the quality is marginal (Pusey et al. 2002). I believe that Lake Junaluska is a source population for Richland Creek, where smaller fish take refuge, so that the population average length is smaller than found in other populations.

In each of the age classes found, the total length fell inside the range of other studied populations (Carlandar 1977). However, average total length was smaller than total lengths for a population of invasive Redbreast Sunfish in southern Virginia (Petrimoulx 1983). Although this location is north of Richland Creek, the drainages are lower in elevation, so temperature differences may account for the larger size, or it may just be differences in habitat conditions.

Lawrence found Redbreast Sunfish reach maturity at about 23 g (1957) or in the second year of life (Hiranvt 1973). I found eggs in an individual 60 mm and 5.2 g, which was aged 0+, much smaller than Lawerence and Hiranvts proposed age of maturity. This population does have a wide range of lengths within ages so it is possible the age/size of maturity is highly varied as well. Using a length of 69 mm as length at maturity, I found greater than 2:1 male to female

ratio. This differs from the 1:1 ratio found by Saecker and Woolcott (1988) in Virginia. A higher number of males may have left Lake Junaluska to avoid other males and to search for a suitable nest location in the flowing water of Richland Creek. Or, although the presence of eggs made it clear that an individual was female, the absence of eggs left questions as to its sex and maturity. Females in the sizes sampled may have not all reached sexual maturity, skewing the estimated sex ratio.

In our first month of sampling, over 50% of the fish were in their second year of life. The oldest fish caught was in its fourth year of life, while Redbreast Sunfish have been found up to eight years old (Webster 1942). This supports an argument that the creek is a sink or juvenile refuge population for a larger source population in the reservoir.

Each of the age groups had a broad range of lengths. This broad range of sizes at specific ages is due to some individuals growing rapidly, while some grow very little over time. These fish can survive in a wide variety of conditions, they can grow rapidly when conditions are optimal or they can survive in sub-optimal conditions.

Seasonal Comparison

Seasonally, the fish in the fall had a distribution similar to the length distribution of the total population, while the fish caught in the spring were smaller. This is due to our removal of fish throughout the year, possibly removing a greater proportion of larger fish, leaving higher numbers of small fish in the spring. Electrofishing is not a perfect removal tool; if the current is too high, it can kill native fish, but if it is too low, it may not fully stun all of the fish that being targeted. Sampling by electrofishing can yield biased catches in regard to size and species of fish, (Dolan and Miranda 2003) as well as habitat characteristics (Rodgers et al.

1992). Richland Creek is a natural creek with vegetation along the banks, creating crevices in rocks and woody debris that make good refuges for small fish.

Site Comparison

Our source-sink hypothesis is supported by the differences in lengths of fish in the sample sites. Site A is closer to the reservoir and had smaller individuals, site C was further away from the reservoir and had larger individuals. If the reservoir is a source population, small fish may have recruited in higher numbers to site A, influencing the sample population more than the sample population at site C. Differences in habitat between the sites could also play a role in differences in total lengths of fish in populations. Site A is wider and has slower moving water than the other two sites. The banks are less steep and there aren't as many large rocks both on the bank and on the bottom of the creek bed. Site C on the other hand, is a narrower stretch of the creek, with swifter moving water, and more large rocks on the bank, as well as in the creek. These large rocks provide crevices that provide cover, as well as habitat for larger prey items.

Diet

The large number of chrionomids found in the stomachs of the redbrest sunfish collected is likely due to their prevalence in the environment and preference for habitat commonly occupied by Redbreast Sunfish. They predominantly live in pool habitats, in slower moving water, where a non-streamlined fish, such as the Redbreast Sunfish can forage easily.

The wide variety of prey items found in the stomachs and lack of strong preference or avoidance suggests that they are generalists. Several fish even consumed crustaceans despite their hard bodies being particularly difficult to digest. Redbreast Sunfish in the Juniata River in Pennsylvania were found to have primarily Ephemeropteras (70.5% dry weight) in their

stomachs, followed by Trichopteras (15.6%) and only 0.9% of their diet consisted of Chironomids (Johnson & Dropkin 1995). In Calder Lake, in New York, the six prey items most commonly eaten by the Redbreast Sunfish were Odonota, terrestrial insects, Trichoptera larvae, Chironomidae Larvae, aquatic beetles, and snails (Thorp et al. 1989). These diets show some overlap with the population of Redbreast Sunfish in Richland Creek, however, the differences indicate that these fish are, in fact, generalists. The ability to eat whatever is available in the environment is characteristic of invasive species, and helps explain how they can persist in a variety of conditions (Harms & Turingan 2012).

Observation of bones and scales in the stomach of one fish indicates that the Redbreast Sunfish is not only eating invertebrates. These fish are generalists and will eat smaller adult and larval fish. The soft bodies of larval and early juveniles prey fishes lose identifiable characteristics within hours of being eaten (Schooley et al. 2008, Legler et al. 2010). The bones in one stomach, as well as evidence that other sunfish eat larval prey fish (Schooley et al. 2008) suggest that competition for food is not the only potential problem native fish face in the presence of this invasive species.

In the fall, oligochaetes comprised about 10% of the invertebrates found in the environment, but were not evident in the fish stomachs. In the spring, stomach contents were scanned with a compound microscope to look for oligochaetes chaetae. Chaetae, and thus oligochaetes, were present in 50 of the 67 fish sampled in the spring. The oligochaetes outnumbered the chironomids in percent occurrence in the spring, with oligochaetes occurring in 75% of the stomachs and chironomids occurring in 69% of the stomachs sampled. This suggests that although no oligochaetes were found in the fall diets, they were most likely a major food item year round for Redbreast Sunfish.

The population of mayflies (Ephemeroptera) in this creek was highly seasonal. The frequency of ephemeropterans in the diet increased from 1% in the fall to 21% in the spring. Although hatching times vary by species, most mayflies hatch in March, April, and May (Elliott 1978), resulting in increased number of larger, more desirable larvae in the environment.

The variation in diets among sites was most likely due to the differences in habitat. Site A was downstream, closer to the reservoir, wider, and had slower moving water. There are also more pools on the sides of the creek, which is generally slow moving water. This slow moving water may have allowed sunfish to search the substrate for these tiny invertebrates without having to fight the current, saving energy.

Invertebrates in Environment

The water quality of Richland Creek has improved after being labeled "poor" by the North Carolina Department of Natural Resources in 1983 and 1985, to being labeled "good" in 2002 and 2007 (NCDENR 2014). In 1964, Messer found almost 1,000 midge larva per square meter from samples in Richland Creek (Messer 1964). Today, the creek has a very diverse assemblage of benthic macroinvertebrates. The high numbers of Ephemeroptera, Plecoptera, and Trichoptera support NCDENR's conclusion that the water quality has improved since being placed on the list of impaired waters under Section 303d of the Clean Water Act (EPA 2012 (b)). As with the diet contents, differences between fall and spring invertebrate numbers are due to seasonal fluctuations of hatching and emerging, especially in ephemerellids. In a diet study of nine different Illinois stream fishes, Angermeier (1982) found seasonal shifts in the size and composition of invertebrates to be more apparent in drift invertebrates than in benthic samples. In the Redbreast Sunfish of Richland Creek, there were higher numbers of hemipterens in the fall

than in the spring, however the increase in ephemerellids was far more noticeable than the variation in drift invertebrates.

Habitat characteristics varied by site and composition of invertebrate populations varied as well. By observation, the water was moving slower through site A than the other sites. This slow moving water in site A may have contributed to the higher numbers of chironomids and other dipterans, while the fast moving, highly oxygenated water at sites B and C were habitat conditions where ephemeropterans and trichopterans are most often found (McCafferty 1998).

Diet to Environment Comparison

Invasive fish are often generalists (Harms & Turingan 2012), which helps them survive in ecosystems that have been disturbed and are inhabitable to more sensitive, native species. The population of Redbreast Sunfish in Richland Creek largely ate what was available at the frequency that it was available. There were two taxa that the fish did not eat in proportion to their availability: ephemeroptera and chironomids. The ephemeroptera appear to have been avoided and the chironomids were preferred.

Ephemeroptera population has very dynamic numbers, seasonally. There were always members of the family Heptageniidae present, as well as members of the Baetidae family, but it was the Ephemerelliidae family that had the most varied frequencies throughout the year. Not a single Ephemerellidae was found in the environment nor in the stomachs of the fish in the fall.

However, in the spring the numbers of Ephemerellidae increased, showing a presence in both stomachs and environment. Although the sunfish ate high numbers of Ephemerellidae while they were plentiful in the environment, because stomachs from all seasons were grouped to increase sample size, the lack of ephemerellidae in the fall resulted in a low food selection index. Mayflies have hard bodies, which may be less desirable than softer, more digestible

prey. Further, most mayflies live sprawled on the bottom of rocks, which may be difficult for sunfish to access (Merritt et al. 2008).

Chironomids were selected for by the fish, shown by their food selection index of 0.37 which was much higher than the other taxa's index numbers. Chironomids are small members of the order Diptera; they have soft bodies and hard, capsulated heads. Their soft bodies are easily digested and they have little protection from predation. They live in all habitats, but were found in higher numbers in the pool habitat, with slow moving water and sandy bottoms.

Another factor that may have contributed to higher numbers of chironomids in the diets than in the benthic sampling is sampling bias. The chrionomids found in the stomachs of the fish were found by sorting under a dissection microscope. The 0.5 mm mesh of the aquatic sampling net used traps most benthic macroinvertebrates, but early instar chironomids could pass through the mesh. Thus, the fish were sampling a broader range of chironomid sizes than were available to my sampling.

Although Strauss' index of food selection is more reliable and less dependent on relative abundance of prey in the environment than many other indexes (Strauss 1979), no index can account for all of the problems associated with comparing stomach contents to environmental samples. Strauss (1979) outlined three difficulties when making such comparisons. First, traditional sampling of benthic macroinvertebrates has been shown to have some degree of unreliability, due to the fauna being attached to the substrate in varying degrees and the stochastic patchiness of these animals (Longhurst 1958). The microhabitat preferred by the prey item may have a significant impact on the susceptibility to predation, but these habitats are often too small or difficult to sample independently by the researcher (O'Brien and Vinyard 1974). Second, habitat sampling and comparison requires the assumption that the amount of

food items in the environment is not altered by the predation of the predator in question. A food item may be consumed until there is very little left in the environment, raising the index higher than it would be if an ecosystem without the predator was sampled. Finally, as with the oligochaetes, digestion rates vary depending on the diet item, and is often temperature dependent (Hess and Rainwater 1939). A soft bodied oligochaetes is going to be digested much faster than a crustacean. Fortunately, all invertebrates found in the environment, with the exception of oligochaetes, have at least some part of their body that is sclerotized, and hence at least partially indigestible.

Conclusion

This population of Redbreast Sunfish differed to varying degrees from other studied populations of Redbreast Sunfish. It was slightly smaller and younger, with more males than females, supporting our hypothesis that the population in Richland Creek may be a sink population for Lake Junaluska, as Richland Creek may serve as a refuge habitat for juvenile fish from Lake Junaluska.

As with many invasive fish, this population of Redbreast Sunfish are generalists, largely preying on whatever is available. This generalist diet may overlap with the native Rock Bass diet, which consists of small crustaceans and insect larvae when small, transitioning to a greater proportion of crayfish and fish at adult sizes (e.g. Elinor and Hadley 1979, Petrimoulx 1983, Probst et al. 1984, Johnson and Dropkin 1993, Mittelbach and Persson 1998). Rock Bass appear to prefer large substrate (boulders and cobble), root wads, undercut banks, and aquatic vegetation (Probst et al. 1984, McClendon and Rabeni 1987). The Redbreast Sunfish we sampled were often captured in similar habitat. Thus Redbreast Sunfish and Rock Bass broadly overlap in body size, diet, and habitat preferences, suggesting the potential for competition.

WORKS CITED

Aiken, M. 2014. The efficacy of small-scale removal of an invasive species. Redbreast sunfish (*Lepomis aurtius*) by electrofishing. MS Thesis, Biology Department, Western Carolina University, Cullowhee, NC.

Anderson, CS. 1995. Measuring and correcting for size selection in electrofishing mark-recapture experiments. Transactions of the American Fisheries Society. 124(5):663-676.

Anderson, RO and SJ Gutreuter. 1983. Length, weight and associated structural indices. pp 283-300 in L.A. Nielsen and D.L. Johnson (eds), Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Angermeier, SL. 1982. Resources seasonality and fish diets in an Illinois stream. Environmental Biology of Fishes 7(3):251-264.

The American Fisheries Society. 2002. Guidelines for the use of fishes in research. Bethesda, Maryland, USA.

Brown, LR, and PB Moyle. 1997. Invading species in the Eel River, California: successes, failures, and relationships with resident species. Environmental Biology of Fisheries 49:271-291.

Burr, B.M., and L.M. Page. 1986. Zoogeography of the fishes of the lower Ohio-upper Mississippi basin. Pages 287-324 *in* Hocutt, C.H., and E.O. Wiley, eds. The zoogeography of North American freshwater fishes. John Wiley and Sons. New York, NY.

Carlander, KD. 1977. Handbook of Freshwater Fishery Biology, v. 2. The Iowa State University Press, Ames, Iowa. p. 40-43.

Carmona-Catot, G, PB Moyle, E Aparicio, PK Crain, LC Thompson, and E Garcia-Berthou. 2010. Brook trout removal as a conservation tool to restore Eagle Lake rainbow trout. North American Journal of Fisheries Management 30(5):1315-1323.

Carrithers, RB and FJ Bulow. 1973. An ecological survey of the west fork of the Obey River, Tennessee with emphasis on the effects of acid mine drainage. Journal of the Tennessee Academy of Science 48(2):65-72.

Davis, JR. 1972. The spawning behavior, fecundity rates, and food habits of the Redbreast Sunfish in southeastern North Carolina. Proceedings of the Annual Conference of Southeastern Associated Game and Fish Commissions 31:556-560.

Dodd, Jr., CK. 1997. Imperiled amphibians: A historical perspective. *In:* Benz, GW and DE Collins (ed.) Aquatic Fauna in Peril: The Southeastern Perspective. Special Publication 1, Southeastern Aquatic Research Institute, Lenz Design and Communications, Decatur, GA p. 165-200.

Dolan, CR and LE Miranda. 2003. Immobiliziation thresholds of electrofishing relative to fish size. Transactions of the American Fisheries Society. 132: 969-976.

Elliott, JM. 1978. Effect of temperature on the hatching time of eggs of *Ephemerella ignita* (Poda) (Ephemeroptera: Ephemerellidae). Freshwater Biology 8: 51-58.

Environmental Protection Agency. 2012 (a). Barber Orchard. http://www.epa.gov/superfund/accomp/factsheets05/barber.htm. Accessed on 27 March 2013.

Environmental Protection Agency. 2012 (b). North Carolina: Richland Creek, Agricultural and wastewater treatment best management practices improve water quality in creek. http://water.epa.gov/polwaste/nps/success319/nc_rich.cfm. Last updated 28 August, 2012. Accessed 12 August, 2014.

Etiner, DA and WC Starnes. 1993. *The Fishes of Tennessee.* Knoxville, TN: The University of Tennessee Press.

Fishbase.org. 2014. *Lepomis auritus*. http://www.fishbase.org/Summary/SpeciesSummary.php?ID=3370&AT=redbreast+sunfish. Accessed 05 November, 2014.

Fisher Huckins, CJ, CW Osenberg, and GG Mittelbach. 2000. Species introductions and their ecological consequences: an example with congeneric sunfish. Ecological Applications 10(2):612-625.

Folkerts, GW. 1997. State and fate of the world's aquatic fauna. *In:* Benz, GW and DE Collins (ed.) Aquatic Fauna in Peril: The Southeastern Perspective. Special Publication 1, Southeastern Aquatic Research Institute, Lenz Design and Communications, Decatur, GA p. 1-16.

Gautreau, MD and RA Curry. 2012. Ecology and status of the Redbreast Sunfish, *Lepomis aurtius,* in Yoho Lake, New Brunswick. Northeastern Naturalist 19(4):653-664.

George, EL and FW Hadley. 1979. Food and habitat partitioning between Rock Bass (*Ambloplites rupestris*) and Smallmouth Bass (*Micropterus dolomieui*) young of the year. Transactions of the American Fisheries Society 108(3):253-261.

Gozlan, RE, JR Britton, I Cowx, and GH Copp. 2010. Current knowledge on non-native freshwater fish introductions. Journal of Fish Biology 76: 751-786.

Harms CA and RG Turingan. 2012. Dietary flexibility despite behavioral stereotypy contributes o successful invasion of the pike killifish, *Belonesox belizanus*, in Florida, USA. Aquatic Invasions 7(4):547-553.

Hess, AD and JH Rainwater. 1939. A method for measuring the food preference of trout. Copeia 3:154-157.

Hiranvat, S. 1973. Preimpoundment age and growth of the Redbreast Sunfish, *Lepomis auritus*, in the proposed West Point Reservoir, Alabama and Georgia. (Abstract) Georgia Academy Science (Cited in Carlander, KD. 1977. Handbook of Freshwater Fishery Biology, v. 2. The Iowa State University Press, Ames, Iowa. p. 40-43.)

Jearld, A., Jr. 1983. Age determination. pp 301-324 in L.A. Nielsen and D.L. Johnson (eds), Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Johnson, JH and DS Dropkin. 1993. Diel variation in diet composition of a riverine fish community. Hydrobiologia 271(3):149-158.

Johnson, JH and DS Dropkin. 1995. Diel feeding chronology of six fish species in the Juniata River, Pennsylvania. Journal of Freshwater Ecology 10(1):11-18.

Lattimore, RE and JT Whitfield Gibbons. 1976. Body condition and stomach contents of fish inhabiting thermally altered areas. American Midland Naturalist 95(1):215-219.

Lawrence, JM. 1957. Life History and Ecology of Centrarchid Fishes. Data for Handbook of Biological Data. p. 9. (Cited in Carlander, KD. 1977. Handbook of Freshwater Fishery Biology, v. 2. The Iowa State University Press, Ames, Iowa. p. 40-43.)

Legler, ND, TB Johnson, DD Heath, and SA Ludsin. 2010. Water temperature and prey size effects on the rate of digestion of larval and early juvenile fish. Transactions of the American Fisheries Society: 139:3, 868-875.

Lepori, F, JR Benjamin, KD Fausch, and CV Baxter. 2012. Are invasive and native trout functionally equivalent predators? Results and lessons from a field experiment. Aquatic Conservation: Marine and Freshwater Ecosystems 22:787-798.

Liao, H, CL Peirce, and JG Larscheid. 2002. Diet dynamics of the adult piscivorous fish community in Spirit Lake, Iowa, USA 1995-1997. Ecology of Freshwater Fish 11:178-189.

Longhurst, AR. 1958. The sampling problem in benthic ecology. New Zealand Ecological Society 6: 8-12.

Ludyanskiy, ML, D McDonald, and D MacNeill. 1993. Impact of the zebra mussel, a bivalve invader. BioScience 43(8):533-544.

McCafferty, WP. 1998. Aquatic Entomology: The Fisherman's and Ecologist's Illustrated Guide to Insects and Their Relatives. Jones and Bartlett Publishers: Sudbury, MA.

McClendon, DD and CF Rabeni. 1987. Physical and biological variables useful for predicting population characteristics of Smallmouth Bass and Rock Bass in an Ozark stream. North American Journal of Fisheries Management 7(1):46-56.

Merritt, RW, KW Cummins, and MB Berg. 2008. An Introduction to the Aquatic Insects of North America: Fourth Edition.Kendall Hunt Publishing Company: Dubuque, IA.

Menhinick, EF. 1991. The freshwater fishes of North Carolina. Raleigh, NC: North Carolina Wildlife Resources Commission.

Messer, J. B. 1964. Survey and classification of the Pigeon River and tributaries, North Carolina. Final Report, Federal Aid in Fish Restoration Job IN. Project F-14-R North Carolina Wildlife Resources Commission.

Miller, JR, JB Anderson, PJ Lechler, SL Kondrad, PF Galdbreath, and EB Salter. 2005.

Influence of temporal variations in water chemistry on Pb isotopic composition of rainbow trout (*Oncorhynchus mykiss*). Science of the Total Environment 350(1-3):204-224.

Mills, EL, JH Leach, JT Carlton, and CL Secor. 1994. Exotic species and the integrity of the Great Lakes: lessons from the past. BioScience 44(10):666-676.

Mittelbach, GG and L Persson. 1998. The ontogeny of piscivory and its ecological consequences. Canadian Journal of Fisheries and Aquatic Sciences 55(6):1454-1465.

Moyle, PB. 1986. Fish introductions into North America: patterns and ecological impact. p.127170. *In:* HA Mooney & JK Drake (ed.) Ecology of Biological Invasions of North America and Hawaii, Springer Verlag, New YorkMoyle, PB, PK Crain, K Whitener, and JF Mount. 2003. Alien fishes in natural streams: fish distribution, assemblage structure, and conservation in the Cosumnes River, California, USA. Environmental Biology of Fishes 68:143-162.

Neal, JW, RL Noble, NM Bacheler, M McGee and CG Lilyestrom. 2001. Freshwater sportfish community investigations and management. Final Report. Federal Aid in Sportfish Restoration Project F-41-2. San Juan, Puerto Rico: Puerto Rico DNER.

North Carolina Department of the Environment and Natural Resources, Division of Water Quality. 2012. Richland Creek Watershed. http://portal.ncdenr.org/web/wq/ps/bpu/urw/richlandcreek. Accessed 26 March, 2013.

North Carolina Department of the Environment and Natural Resources, Division of Water Quality. 2014. NCDWR Stream Fish Community Assessment Program: NCIBI

Scores and Ratings. http://portal.ncdenr.org/web/wq/ess/bau/ncibi-scores. Accessed 26 August, 2014.

O'Brien, WJ and GL Vinyard. 1974. Comment on the use of Ivlev's electivity index with planktivorous fish. Journal of the Fisheries Research Board of Canada 31: 1427-1429.

Office of Technology and Assessment (OTA). 1993. Harmful nonindigenous species in the United States. US Congress, Washington, DC.

Orwig, DA, DR Foster, and DL Mausel. 2002. Landscape patterns of hemlock decline in New England due to the introduced hemlock woolly adelgid. Journal of Biogeography 29(10/11):1475-1487.

Petrimoulx, HJ. 1983. The life history and distribution of the Roanoke bass *Ambloplites cavifrons* (Cope) in Virginia. American Midland Naturalist 110(2): 338-35

Probst, WE, CF Rabeni, WG Covington, and RE Marteney. 1984. Resource use by stream-dwelling Rock Bass and Smallmouth Bass. Transactions of the American Fisheries Society 113(3):283-294.

Pusey, BJ, Arthington, AH, Close PG, and JR Bird. 2002. Larval fishes in rainforest streams: Recruitment and microhabitat use. Proceedings of the Royal Society of Queensland 110: 27-46.

Raborn, SW, LE Miranda, and MT Driscoll. 2004. Diet overlap and consumption patterns suggest seasonal flux in the likelihood for exploitative competition among piscivorous fishes. Ecology of Freshwater Fish 13:276-284.

Rahel F and J Olden. 2008. Assessing the effects of climate change on aquatic invasive species. Conservation Biology 22(3):521-533.

Rodgers, JD, MF Solazzi, SL Johnson, and MA Buckman. 1992. Comparison of three techniques to estimate juvenile coho salmon populations in small streams. North American Journal of Fisheries Management 12(1): 79-86.

Saecker, JR and WS Woolcott. 1988. The Redbreast Sunfish *Lepomis aurtius* in a thermally influenced section of the James River, Virginia, USA. Virginia Journal of Science 39(1): 1-17.

Sammons, SM and MJ Maceina. 2006. Changes in diet and food consumption of largemouth bass following large-scale hydrilla reduction in Lake Seminole, Georgia. Hydrobiologia 560:109-120.

Scott, RJ, DLG Noakes, FWH Beamish, and LM Carl. 2003. Chinook salmon impede Atlantic salmon conservation in Lake Ontario. Ecology of Freshwater Fish 12:66.73.

Schooley, JA, AP Karam, BR Kesner, PC Marsh, CA Pacey and DJ Thornbrugh. 2008. Detection of larval remains after consumption by fishes. Transactions of the American Fisheries Society 137:4, 1044-1049.

Shea, K and P Chesson. 2002. Community ecology theory as a framework for biological invasions. TRENDS in Ecology and Evolution 17(4):170-176.

Stoddard, JL, DP Larsen, CP Hawkins, RK Johnson, and RH Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 16(4):1267-1276.

Strauss, RE. 1979. Reliability estimates for Ivlev's Electivity Index, the Forage Ratio, a proposed linear index of food selection. Transactions of the American Fisheries Society. 108:344-352.

Thorp, JH, LD Goldsmith, JA Polgreen, and LM Mayer. 1989. Foraging patterns of nesting and nonnesting sunfish Centrarchidae *Lepomis aurtius* and *Lepomis gibbosus*. Canadian Journal of Fisheries and Aquatic Sciences. 46(8):1342-1346.

Webster, DA. 1942. The life histories of some Connecticut fishes. p. 122-227. A fishery survey of important Connecticut Lakes. Bulletin Connecticut Geology Natural History Survey 63: 1339. (Cited in Carlander, KD. 1977. Handbook of Freshwater Fishery Biology, v. 2. The Iowa State University Press, Ames, Iowa. p. 40-43.)

Werner, EE and DJ Hall. 1977. Competition and habitat shift in two sunfishes (Centrarchidae). Ecology 58(4): 869-876.

Wildish, DJ and MLH Thomas. 1985. Effects of dredging and dumping on benthos of St. John Harbor, Canada. Marine Environmental Research 15(1):45-58.

Windell, JT. 1971. Food analysis and rate of digestion. *In*: Ricker, WE. (ed.) Methods for Assessment of Fish Production in Fresh Waters. International Biological Programme by Blackwell Scientific Publications, Oxford and Edinburgh, England.

Vila-Gispert, A, C Alcaraz and E García-Berthou. 2005. Life-history traits of invasive fish in small Mediterranean streams. Biological Invasions 7:107-11

TABLES

Table 1. Numbers and percentages of *Lepomis auritus* of each sex, as well as ratio of male to female, in known fish greater and equal to 69 mm in length.

Sex	Immature	Male	Female
Total	105	114	52
Percent	38.7	42.1	19.2
Male: Female Ratio		2.19	1

Table 2. ANOVA summary for differences in total length among the three sample sites.

Source	df	SS	F	P
Site	2	14084	13.23	<0.0001
Error	268	142655		
Total	270	156739		

Table 3. Summary of Tukey's pair-wise comparisons among means.

Hypothesis	Estimate	SE	t	P
B -A=0	8.117	3.474	2.337	0.052
C -A=0	17.232	3.376	5.105	<0.001
C -B=0	9.115	3.932	2.318	0.055

FIGURES

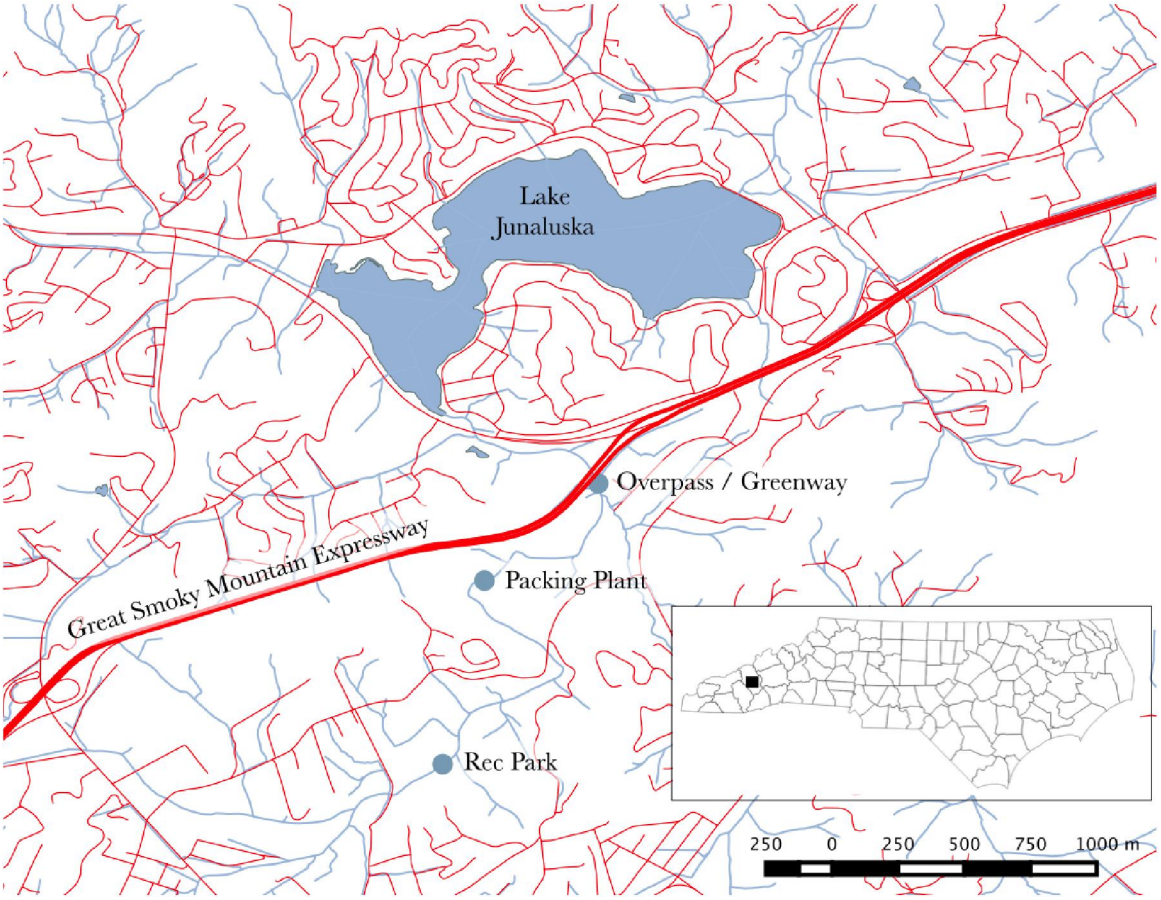

Figure 1. Map of study area. Study reaches A, B, and C correspond to Overpass/Greenway, Packing Plant, and Rec Park, respectively.

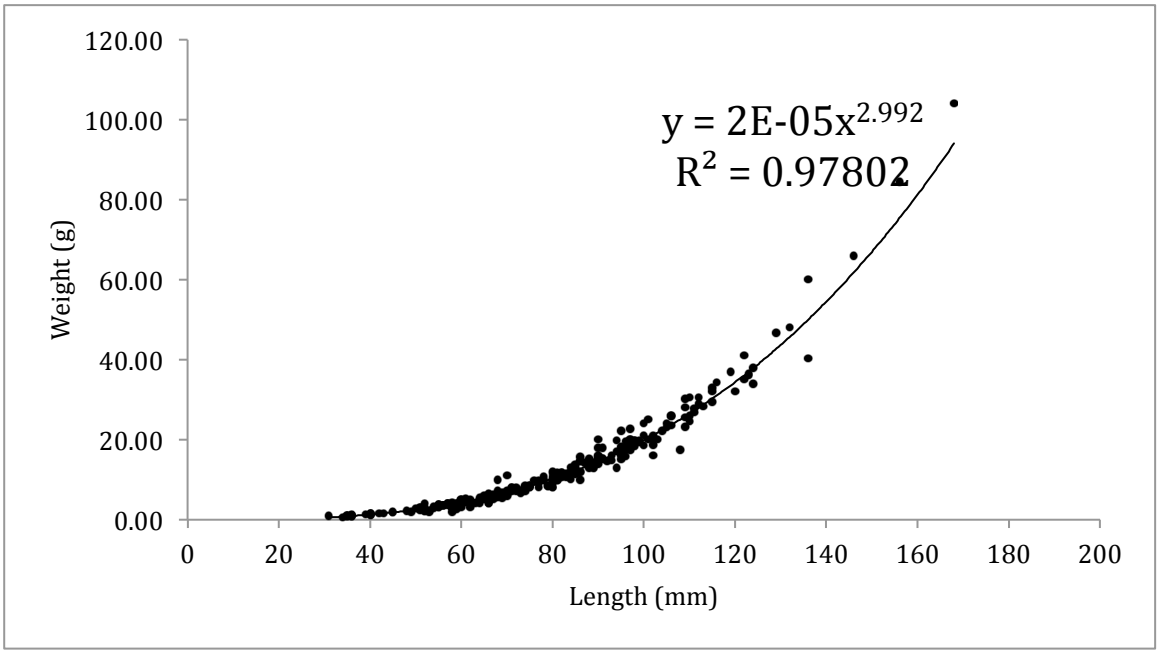

Figure 2. Weight as a function of total length for each of the 271 *Lepomis auritus* specimens collected.

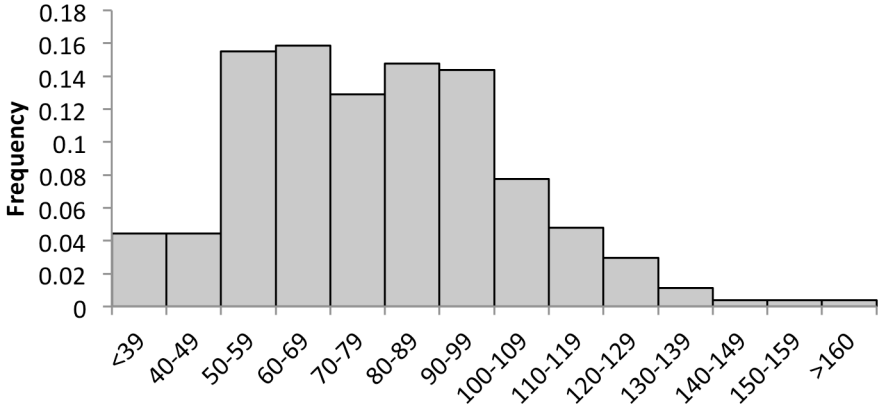

Figure 3. Total length frequency distribution of sampled *Lepomis auritus* .

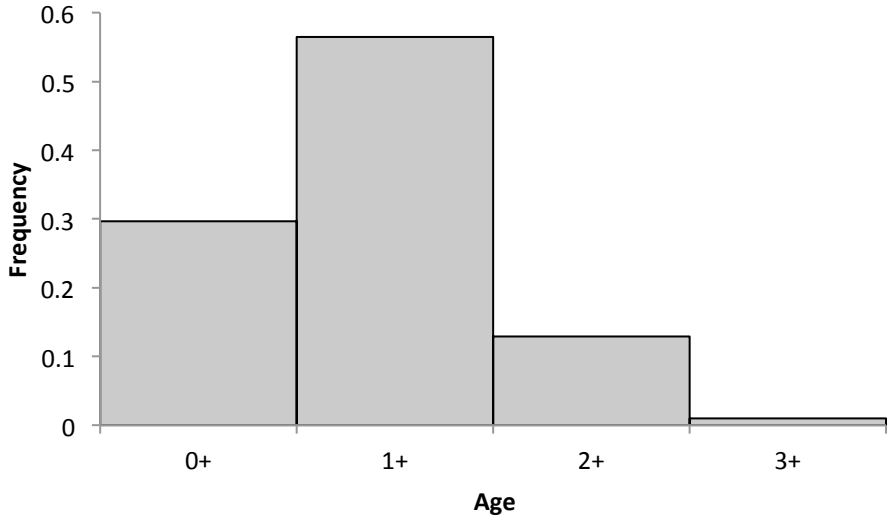

Figure 4. Relative frequency of *Lepomis auritus* caught in September, by age class.

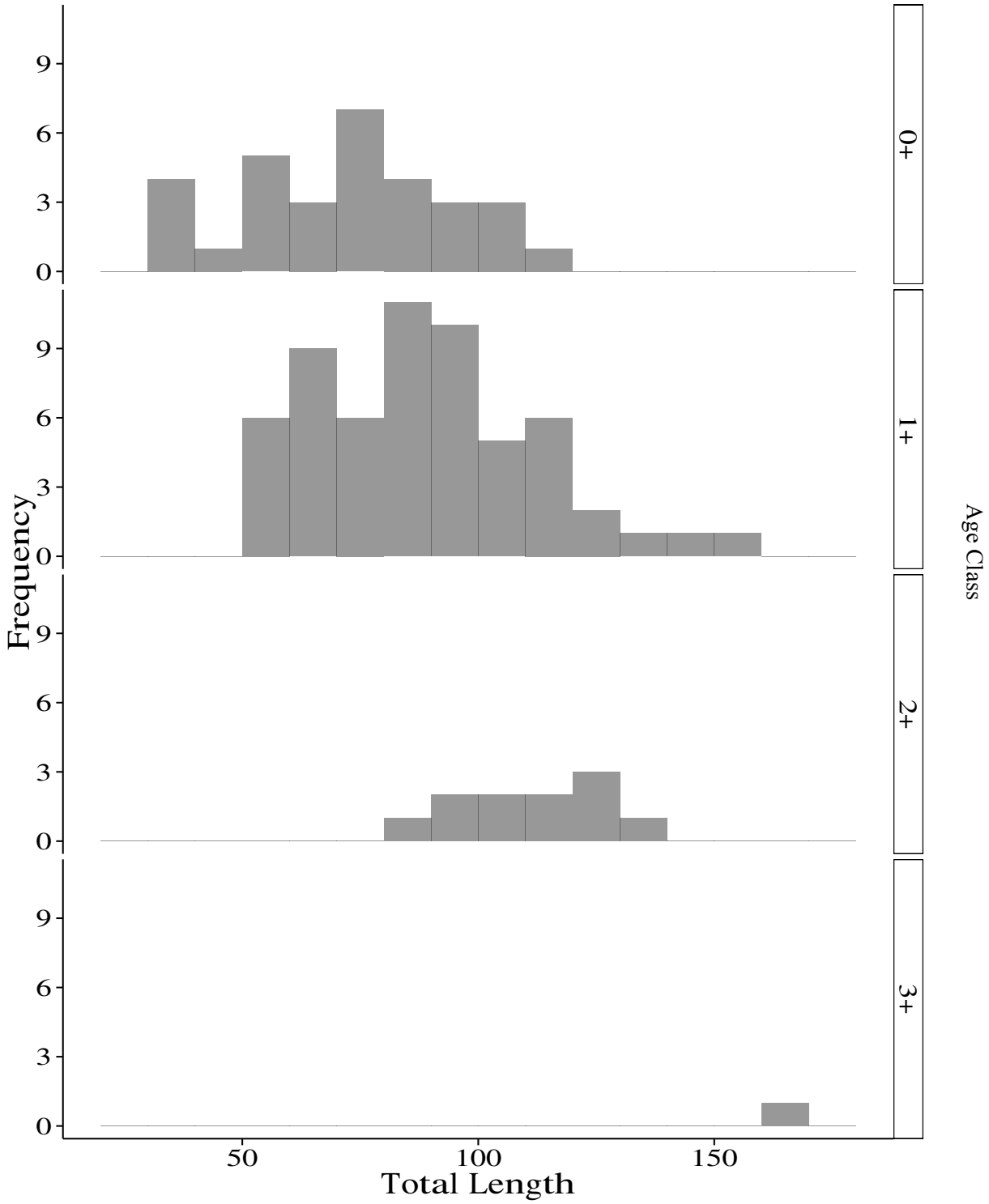

Figure 5. Total length frequency distribution of sampled *Lepomis auritus* in each age class.

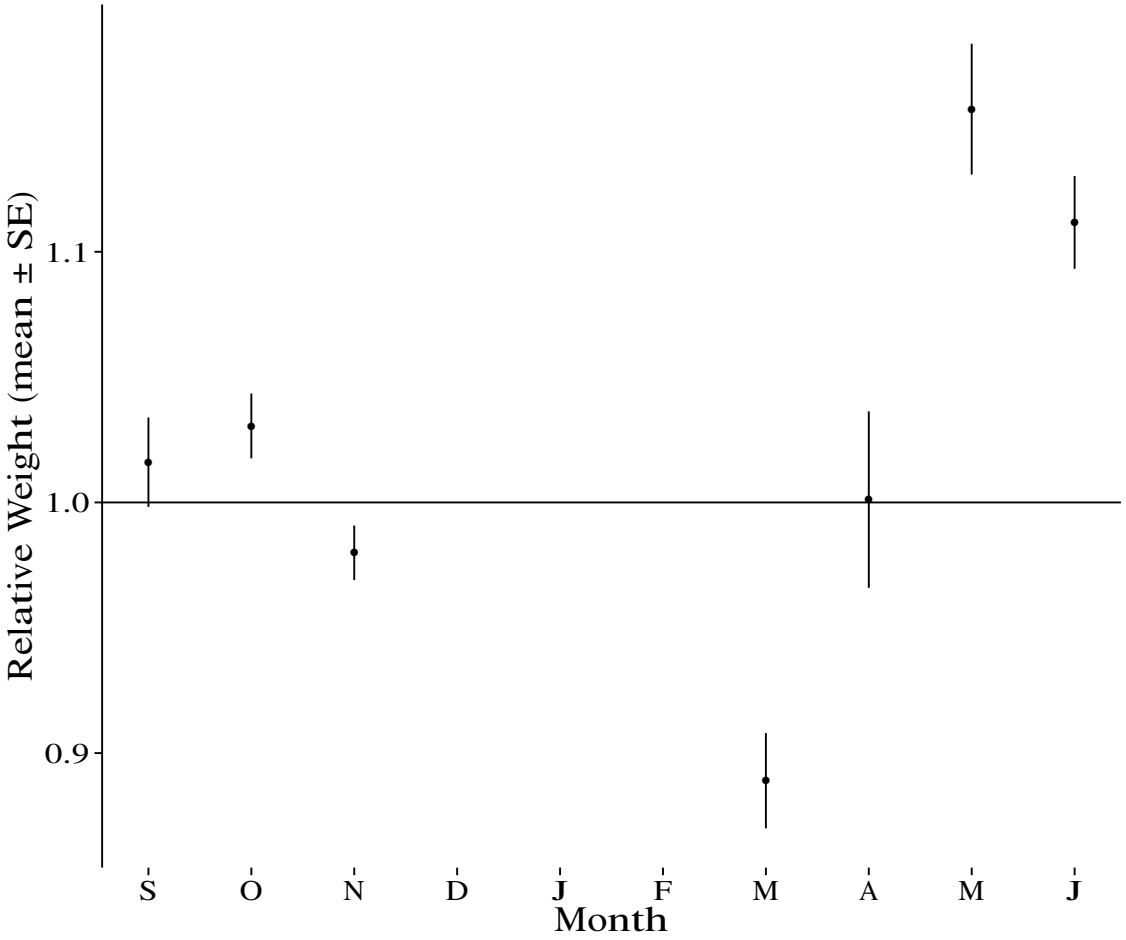

Figure 6. Relative weight of sampled *Lepomis auritus* based on the length-weight regression for all fish sampled. There was no evidence of differences among sites, but differences among sample dates was significant ($P < 0.0001$).

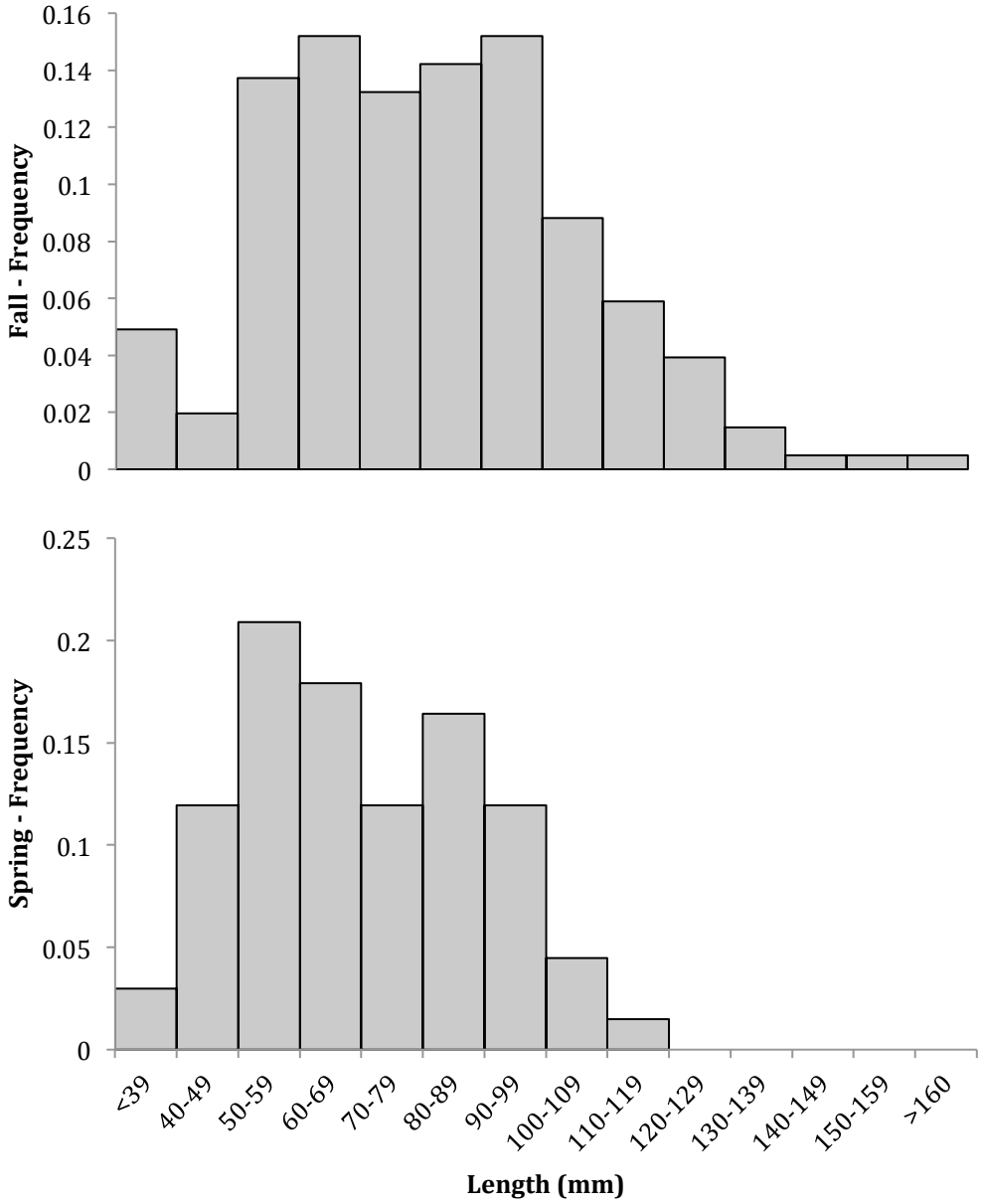

Figure 7. Total length frequency distributions of sampled *Lepomis auritus* pooled across sites, by season.

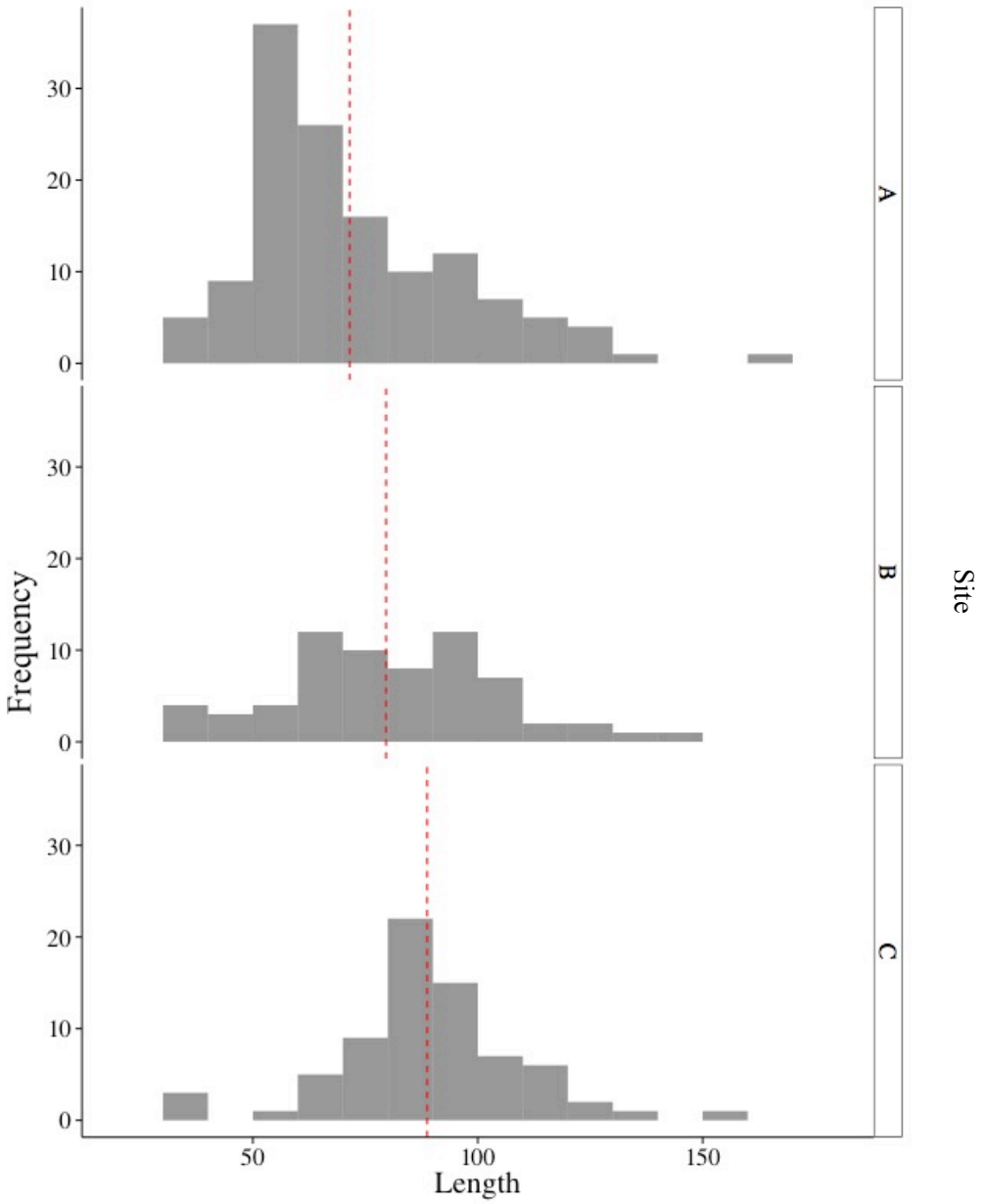

Figure 8. Total lengths of sampled *Lepomis auritus* , by site, pooled across seasons. The dashed vertical lines represent the mean lengths at each site.

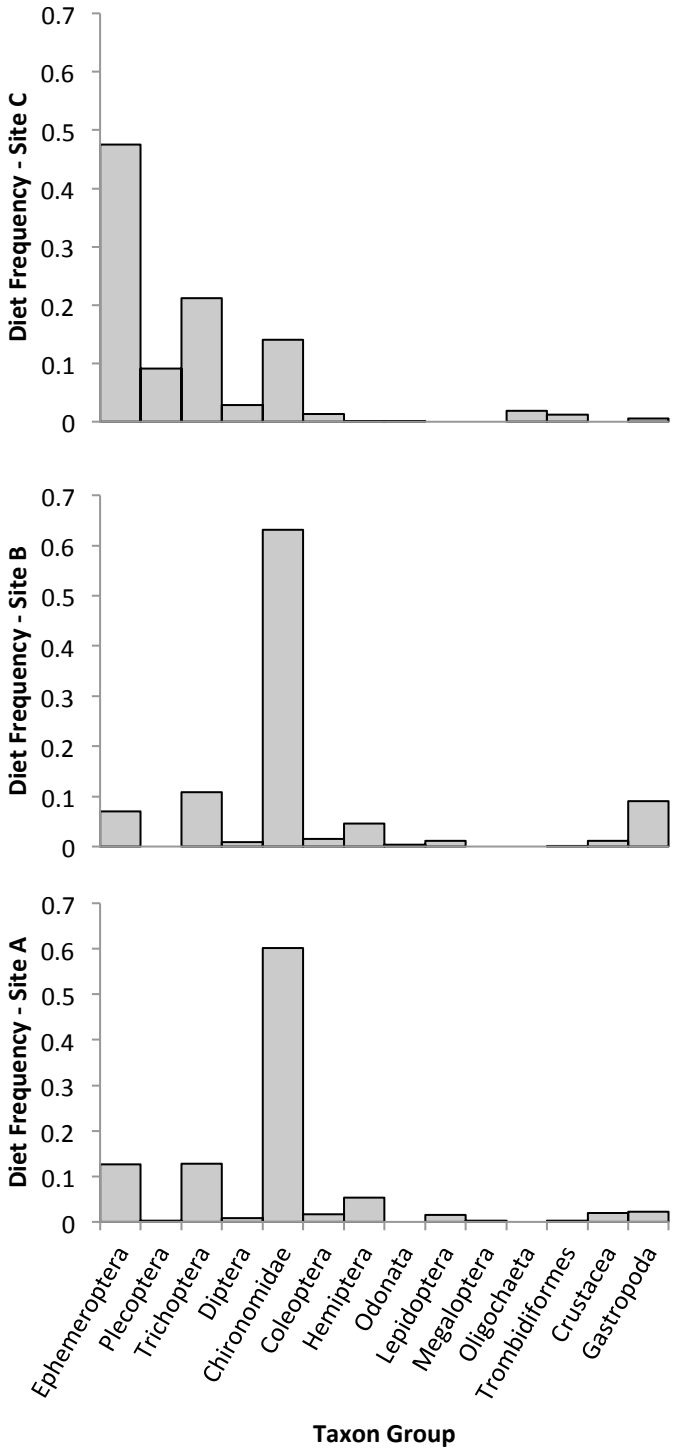

Figure 9: Frequency of diet items found in the stomachs of sample *Lepomis auritus* , pooled across seasons, by site.

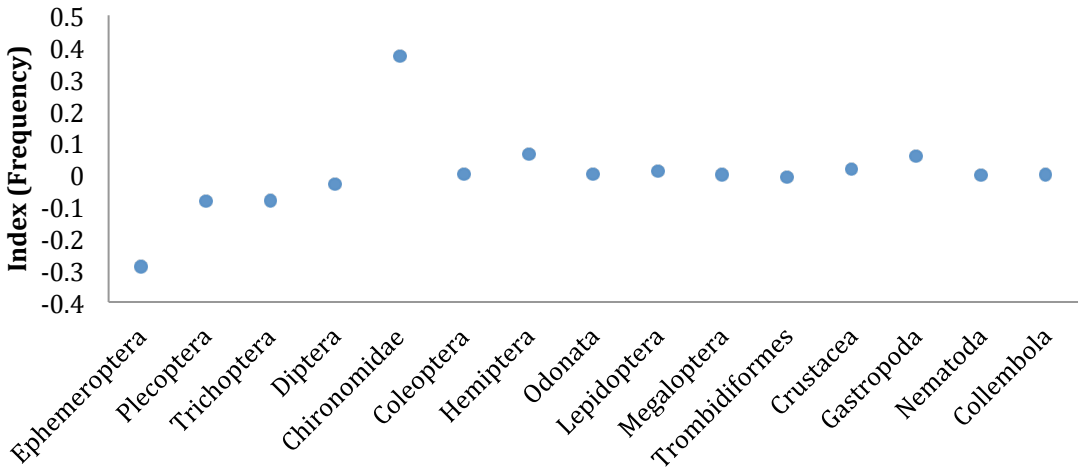

Figure 10. Strauss' linear index of food selection of sampled *Lepomis auritus* for 15 taxonomic invertebrate groups.

APPENDIX A: INVERTEBRATES IN ENVIRONMENT

	090813-A-F	090813-A-K	090813-A-N	090813-A-p	091413-B-F	091413-B-K	091413-B-N	091413-B-P	092813-C-F	092813-C-K	092813-C-N	092813-C-P
Ephemeroptera												
Ephemeroptera (p)												
Baetidae	4	8	15	4	11	1	3		8	2	3	
McCaffertium	1	3	1	1	1	1				2		
Stenacron							1			1		
Epeorus		1			1							
Cinygmula							1		1			
Rhithrogena												
Leucrocuta												
Heptagenia												
Leptophlebiidae												
Habrophlebiodes							1					
Leptophlebia												
Ephemerellidae												
Ephemerella												
Eurylophella												
Plecoptera												
Chloroperlidae	1									1		
Perlidae												
Paragnetina	1	1			1	3	1		4			
Agnetina										1		
Acroneuria												
Pteronarcys										1		
Paracapnia												
Leuctra												
Isoperla												
Trichoptera												
Trichoptera (p)												
Hydropsychiidae (p)						1						
Hydropsyche	1	12			4	9	2	1		15	3	
Cheumatophyche	2	3	1		1	2			1	7	1	
Glossosomatidae (p)		1										
Glossosoma					1	1						
Dolophilodes	1	3							1			
Rhyacophila					2				1		1	

Leptoceridae								1				
Polycentropodidae									1			
Hydroptilidae												
Diptera							1					
Diptera (p)												
Diptera (a)												
Chrionomidae	2	3		5	6	3	1	3	1	4	1	2
Chironomidae (p)												
Chironomidae (a)			1									
Simuliidae	9	1			1							
Simuliidae (p)		1										
Tipulidae												
Tipulidae (p)												
Athericidae							1					
Syrphidae												
Ceratopogonidae												
Coleoptera					1							
Psephenidae		3				1						
Elmidae									1	1		
Hemiptera												
Corixidae												
Gerridae												
Odonata												
Boyeria												
Calopteryx												
Lepidoptera												
Megaloptera												
Oligochaeta					1	1	2	2				
Nematoda	1						1					
Collembola												
Trombidiformes												
Isopoda							1	2				
Snail												
Ferrissia rivularis												
Misc.												
Misc. (p)												

	101913-A-F	101913-A-K	101913-A-N	101913-A-P	103013-B-F	103013-B-K	103013-B-N	103013-B-P	102613-C-F	102613-C-K	102613-C-N	102613-C-P
Ephemeroptera												
Ephemeroptera (p)												
Baetidae	1		1						2			
McCaffertium	5	4	1		3	7		2	3	1	6	
Stenacron	1											
Epeorus						1	1					
Cinygmula			1								1	
Rhithrogena		1		1			1		1			
Leucrocuta												
Heptagenia												
Leptophlebiidae												
Habrophlebiodes												
Leptophlebia												
Ephemerellidae					1				1	1		
Ephemerella												
Eurylophella												
Plecoptera												
Chloroperlidae	1	3	2						2	1	8	
Perlidae												
Paragnetina	3	3			2	1	1	1				
Agnetina		3			2	6			3			
Acroneuria												
Pteronarcys												
Paracapnia												
Leuctra												
Isoperla												
Trichoptera												
Trichoptera (p)												
Hydropsychiidae (p)												
Hydropsyche		7	1		1	11	2		12	5	6	
Cheumatophyche	4	5			1	12			3	3	4	
Glossosomatidae (p)												
Glossosoma		8	2		1	2						
Dolophilodes	5	7			1	3			4			
Rhyacophila	1								1			
Leptoceridae												
Polycentropodidae												
Hydroptilidae		2										
Diptera												

Diptera (p)												
Diptera (a)												
Chrionomidae	10	11	9	1	3	8	3	4	2	2	3	1
Chironomidae (p)	1	2	3				1		1			
Chironomidae (a)												
Simuliidae	1											
Simuliidae (p)												
Tipulidae	1		1				2		2			
Tipulidae (p)												
Athericidae												
Syrphidae					1							
Ceratopogonidae			1									
Coleoptera									1			
Psephenidae		1			1	2			1			
Elmidae							1		1		1	
Hemiptera											1	
Corixidae								1				
Gerridae												
Odonata												
Boyeria				1								
Calopteryx				2								
Lepidoptera	1							1				
Megaloptera												
Oligochaeta	7	6	1	6	23	8	4	7				1
Nematoda												
Collembola												
Trombidiformes			1				1		1			
Isopoda												
Snail												
Ferrissia rivularis												
Misc.												
Misc. (p)												

	111313-A-F	111313-A-K	111313-A-N	111313-A-P	111713-B-F	111713-B-K	111713-B-N	111713-B-P	112513-C-F	112513-C-K	112513-C-N	112513-C-P
Ephemeroptera												
Ephemeroptera (p)												
Baetidae	1								2			1
McCaffertium	5	1			7	3	2		3	1	2	1
Stenacron												
Epeorus					2							
Cinygmula					1	1	1					
Rhithrogena	5		4		3	1	4		8		2	
Leucrocuta												
Heptagenia												
Leptophlebiidae												
Habrophlebiodes												
Leptophlebia												
Ephemerellidae												
Ephemerella			1		4				2	1	2	
Eurylophella					1							
Plecoptera												
Chloroperlidae	5	1	3		2	3			7		6	
Perlidae												
Paragnetina					2	1			1			
Agnetina	1		1		5		1		1		3	
Acroneuria												
Pteronarcys								1				
Paracapnia												4
Leuctra												2
Isoperla												
Trichoptera												
Trichoptera (p)												
Hydropsychiidae (p)												
Hydropsyche	4	3	4	1	8	9	4		4	14	5	
Cheumatophyche	1	2	2		7	3	3			5	3	
Glossosomatidae (p)												
Glossosoma	1	2				1			1			
Dolophilodes		2			2							
Rhyacophila	1	2			4				3			
Leptoceridae												
Polycentropodidae												
Hydroptilidae						1						
Diptera												

Diptera (p)												
Diptera (a)												
Chrionomidae	4	17	14	3	28	22	3		16	5	7	2
Chironomidae (p)	2		1		3				3		1	1
Chironomidae (a)									1			
Simuliidae											1	
Simuliidae (p)												
Tipulidae			1				1	1		1		1
Tipulidae (p)												
Athericidae	1		2									
Syrphidae												
Ceratopogonidae												
Coleoptera												
Psephenidae							1					
Elmidae					1		1					
Hemiptera												
Corixidae												
Gerridae												
Odonata												
Boyeria												
Calopteryx												
Lepidoptera												
Megaloptera												
Oligochaeta	8	1	5	2	1		3		4		2	3
Nematoda												
Collembola												
Trombidiformes												
Isopoda												
Snail												
Ferrissia rivularis												
Misc.												
Misc. (p)												

	032414-A-K	032414-A-F	032414-A-N	032414-A-P	032314-B-K	032314-B-F	032314-B-N	032314-B-P	032314-C-K	032314-C-F	032314-C-N	032314-C-P
Ephemeroptera												
Ephemeroptera (p)				1								
Baetidae		9	1		1	2	1		5	8	4	
McCaffertium	1	1	4		5		3	2		2	1	
Stenacron												
Epeorus		1			9	2	1		14	5	2	
Cinygmula												
Rhithrogena	1	21	1			3	1		7	2	3	
Leucrocuta												
Heptagenia												
Leptophlebiidae												
Habrophlebiodes												
Leptophlebia												
Ephemerellidae												
Ephemerella	4	4	70	10	36	23	20	12	16	41	24	14
Eurylophella												
Plecoptera												
Chloroperlidae	2	2	5		1	4	3		1	4	5	
Perlidae												
Paragnetina						3	1					
Agnetina						2	3			1		
Acroneuria												
Pteronarcys												
Paracapnia												
Leuctra												
Isoperla		15								2	2	
Trichoptera												
Trichoptera (p)					1							
Hydropsychiidae (p)												
Hydropsyche	1	2	1		31	2	3		7	1		
Cheumatophyche	1				23		2		3	1		
Glossosomatidae (p)	4											
Glossosoma	5	1							1			
Dolophilodes		1	1		1	1			2			
Rhyacophila		2										
Leptoceridae												
Polycentropodidae												
Hydroptilidae												
Diptera					1							

Diptera (p)													
Diptera (a)					1					1			
Chrionomidae	27		4		8			3	17		2	1	
Chironomidae (p)				1						1			
Chironomidae (a)													
Simuliidae										1		1	
Simuliidae (p)													
Tipulidae			1			1	3				1		
Tipulidae (p)													
Athericidae													
Syrphidae													
Ceratopogonidae													
Coleoptera													
Psephenidae		2											
Elmidae													
Hemiptera													
Corixidae													
Gerridae													
Odonata												1	
Boyeria													
Calopteryx													
Lepidoptera													
Megaloptera													
Oligochaeta					2			1					
Nematoda			1		1								
Collembola													
Trombidiformes			1		1			3					
Isopoda													
Snail	2												
Ferrissia rivularis													
Misc.					1								
Misc. (p)													

	041814-A-F	041814-A-K	041814-A-N	041814-A-P	042414-B-F	042414-B-K	042414-B-N	042414-B-P	041714-C-F	041714-C-K	041714-C-N	041714-C-P
Ephemeroptera												
Ephemeroptera (p)												
Baetidae						4	2			1		1
McCaffertium					1			1			2	
Stenacron												
Epeorus					6				1		1	
Cinygmula												
Rhithrogena	3	2	2		1	2	1		5	3	4	
Leucrocuta											1	
Heptagenia												
Leptophlebiidae												
Habrophlebiodes												
Leptophlebia												
Ephemerellidae												
Ephemerella	11	14	4	1	7	1	11	4	20	5	19	3
Eurylophella												
Plecoptera												
Chloroperlidae	3	1	2			1	1		1		1	1
Perlidae												
Paragnetina					2							
Agnetina						1						
Acroneuria											1	
Pteronarcys												
Paracapnia												
Leuctra												
Isoperla									1			
Trichoptera												
Trichoptera (p)	1	1			4					2		
Hydropsychiidae (p)												
Hydropsyche	1	5			4	2	4			1	3	
Cheumatophyche		2				1						
Glossosomatidae (p)		9								1		
Glossosoma		3										
Dolophilodes	1											
Rhyacophila	1											
Leptoceridae												
Polycentropodidae												
Hydroptilidae										3		
Diptera												

Diptera (p)											
Diptera (a)											
Chrionomidae	10	2	1	1		2	2	3	10	3	3
Chironomidae (p)											
Chironomidae (a)											
Simuliidae											
Simuliidae (p)											
Tipulidae	4	1	1		1	4	2		2	1	
Tipulidae (p)						1			1		
Athericidae											
Syrphidae											
Ceratopogonidae											
Coleoptera											
Psephenidae		1			1	2					
Elmidae										1	
Hemiptera											
Corixidae											
Gerridae											
Odonata											
Boyeria											
Calopteryx											
Lepidoptera											
Megaloptera											
Oligochaeta	1			1			1				
Nematoda											
Collembola											
Trombidiformes											
Isopoda											
Snail									2		
Ferrissia rivularis		2									
Misc.											
Misc. (p)						3					

	050414-A-F	050414-A-F	050414-A-K	050414-A-N	050414-A-P	052114-B-F	052114-B-K	052114-B-N	052114-B-P	052114-C-F	052114-C-K	052114-C-N	052114-C-P
Ephemeroptera													
Ephemeroptera (p)													
Baetidae		2	2	4		5		1	1	4	2	16	1
McCaffertium													
Stenacron													
Epeorus							1			2	5	1	
Cinygmula													
Rhithrogena		4		1			1	2		1			
Leucrocuta							2	3		1	3	1	
Heptagenia													
Leptophlebiidae										1			
Habrophlebiodes													
Leptophlebia													
Ephemerellidae													
Ephemerella		9	6	4	4	2		1	1	2	6	13	1
Eurylophella													
Plecoptera													
Chloroperlidae		2						2					
Perlidae													
Paragnetina							2						
Agnetina			1				1						
Acroneuria													
Pteronarcys													
Paracapnia													
Leuctra													
Isoperla													
Trichoptera													
Trichoptera (p)			6										
Hydropsychiidae (p)													
Hydropsyche		1	2				2						
Cheumatophyche							1				1		
Glossosomatidae (p)													
Glossosoma		1									1		
Dolophilodes		2											
Rhyacophila			1										
Leptoceridae													
Polycentropodidae													
Hydroptilidae													
Diptera													

Diptera (p)										1		
Diptera (a)											1	1
Chrionomidae	1	4	2	4	2		2		1		2	
Chironomidae (p)												
Chironomidae (a)												
Simuliidae	1											
Simuliidae (p)												
Tipulidae	1	3								1		
Tipulidae (p)		1										
Athericidae												
Syrphidae												
Ceratopogonidae					1		1		3			
Coleoptera												
Psephenidae	1									1		
Elmidae											1	
Hemiptera												
Corixidae												
Gerridae												
Odonata												
Boyeria												
Calopteryx												
Lepidoptera												
Megaloptera												
Oligochaeta				1								
Nematoda												
Collembola												
Trombidiformes								1	1		2	
Isopoda												
Snail												
Ferrissia rivularis		2				1				2		
Misc.												
Misc. (p)		1				1						

	062214-A-F	062214-A-K	062214-A-N	062214-A-P	062314-B-F	062314-B-K	062314-B-N	062314-B-P	062414-C-F	062414-C-K	062414-C-N	062414-C-P
Ephemeroptera												
Ephemeroptera (p)												
Baetidae	1	1	1	2	8	1	1	1	9	1	5	
McCaffertium												
Stenacron												
Epeorus												
Cinygmula												
Rhithrogena									1		1	
Leucrocuta		1	1			2	1					
Heptagenia							1					
Leptophlebiidae												
Habrophlebiodes												
Leptophlebia							1		1			
Ephemerellidae												
Ephemerella									1			
Eurylophella												
Plecoptera												
Chloroperlidae	1		1									
Perlidae						1	1					
Paragnetina							3	1		1		
Agnetina	1		1			1					1	
Acroneuria												
Pteronarcys												
Paracapnia												
Leuctra												
Isoperla												
Trichoptera												
Trichoptera (p)		1				1			1			
Hydropsychiidae (p)												
Hydropsyche		6	1		3	7	2	3	8	8	3	
Cheumatophyche	4				3	2	2			1		
Glossosomatidae (p)		1				2						
Glossosoma	1	4				2						
Dolophilodes					1		1					
Rhyacophila								1				
Leptoceridae												
Polycentropodidae												
Hydroptilidae												
Diptera												

Diptera (p)	1											
Diptera (a)												
Chrionomidae		3	4	2		3	1	4	3	1	2	2
Chironomidae (p)												
Chironomidae (a)												
Simuliidae					2							
Simuliidae (p)												
Tipulidae	1	1	2									
Tipulidae (p)											1	
Athericidae												
Syrphidae												
Ceratopogonidae			1									
Coleoptera												
Psephenidae		1			1					1		
Elmidae												
Hemiptera												
Corixidae												
Gerridae				2								
Odonata												
Boyeria												
Calopteryx												
Lepidoptera												
Megaloptera							2					
Oligochaeta	1	2		2		2		1	1		1	2
Nematoda												
Collembola		1					1					
Trombidiformes	1		1	1	2		1	1	1		4	
Isopoda				1								
Snail						1	1					
Ferrissia rivularis		1										
Misc.												
Misc. (p)												

APPENDIX B: FISH DATA

Fish ID	Length (mm)	Width (g)	Sex	Age (years)
090813-A1	123	36	F	2
090813-A2	102	20	M	1
090813-A3	86	10	M	1
090813-A4	102	16	M	0
090813-A5	94	13	F	2
090813-A6	64	5	M	1
090813-A7	59	3	M	0
090813-A8	60	5	M	1
090813-A9	58	2	M	1
090813-A10	31	<1	M	0
090813-A11	60	3	M	1
090813-A12	62	3	M	1
090813-A13	58	3	M	1
090813-A14	95	15	M	1
090813-A15	51	3	M	1
090813-A16	53	2	M	0
090813-A17	70	7	M	1
090813-A18	119	37	M	2
090813-A19	168	104	U	3
090813-A20	122	35	M	1
090813-A21	105	24	U	1
090813-A22	102	21	F	1
090813-A23	80	10	U	1
090813-A24	52	3	M	1
090813-A25	88	13	M	0
090813-A26	91	18	M	0
090813-A27	112	29	F	1
090813-A28	95	16	M	1
090813-A29	66	6	M	0
090813-A30	45	2	M	0
090813-A31	71	8	F	0
090813-A32	58	3	M	0
090813-A33	59	4	M	1
090813-A34	51	3	M	0
090813-A35	52	4	M	0
091413-B1	70	11	M	
091413-B2	97	19	M	1

091413-B3	68	10	M	1
091413-B4	90	20	M	1
091413-B5	84	12	M	0
091413-B6	80	12	F	1
091413-B7	115	32	F	1
091413-B8	106	26	F	2
091413-B9	97	20	F	0
091413-B10	60	4	M	0
091413-B11	136	60	M	2
091413-B12	81	10	M	1
091413-B13	78	10	M	1
091413-B14	68	6	M	1
091413-B15	80	8	M	2
091413-B16	80	8	M	1
091413-B17	72	8	M	0
091413-B18	67	6	M	1
091413-B19	57	4	M	1
091413-B20	66	4	M	1
091413-B21	106	26	M	1
091413-B22	146	66	M	1
091413-B23	110	26	M	1
091413-B24	93	16	M	0
091413-B25	120	32	M	2
091413-B26	63	4	U	1
091413-B27	103	20	M	2
091413-B28	78	10	M	0
091413-B29	124	38	F	2
091413-B30	100	24	F	1
091413-B31	70	6	M	0
091413-B32	71	8	M	1
091413-B33	74	8	M	1
091413-B34	66	4	M	0
091413-B35	74	8	M	0
091413-B36	90	14	F	2
091413-B37	36	<2	M	0
092913-C1	129	46.7	M	1
092913-C2	97	20.09	F	1
092913-C3	115	33	M	2
092913-C4	84	11.8	M	1
092913-C5	87	14.2	F	1
092913-C6	106	23.6	M	0
092913-C7	94	17.2	F	1
092913-C8	96	17.4	M	1

092913-C9	90	14.9	M	1
092913-C10	35	1	M	0
092913-C11	34	0.7	M	0
092913-C12	112	30.6	F	1
092913-C13	132	48.2	M	1
092913-C14	111	27.8	M	1
092913-C15	97	17.3	M	1
092913-C16	82	10.5	M	1
092913-C17	113	28.4	M	0
092913-C18	83	11.6	M	1
092913-C19	82	11.7	M	1
092913-C20	89	14.2	M	0
092913-C21	88	15.2	F	0
092913-C22	86	14.5	M	1
092913-C23	156	84.5	M	1
092913-C24	115	29.5	F	1
092913-C25	77	9.2	F	1
092913-C26	75	8.3	F	1
092913-C27	109	30.2	M	0
092913-C28	71	7.6	M	0
092913-C29	77	9.8	M	0
092913-C30	98	19.6	M	1
101913-A1	71	7.3	M	1
101913-A2	84	13.1	M	1
101913-A3	56	3.6	M	1
101913-A4	61	5.3	M	0
101913-A5	75	8.6	M	0
101913-A6	72	7.2	M	0
101913-A7	56	3.6	M	1
101913-A8	110	24.7	M	1
101913-A9	57	3.7	M	1
101913-A10	69	5.5	M	1
101913-A11	75	8.7	M	1
101913-A12	66	6.3	F	1
101913-A13	122	41.2	F	2
101913-A14	110	30.5	M	1
101913-A15	74	8.7	M	0
101913-A16	55	3.7	M	1
101913-A17	55	3.7	M	0
101913-A18	61	4.4	M	1
101913-A19	62	4.9	M	0
101913-A20	58	3.8	M	0
101913-A21	54	3.3	M	0

101913-A22	35	1	M	0
101913-A23	55	3.4	M	0
101913-A24	75	8	M	1
101913-A25	66	6.6	M	1
101913-A26	95	16.7	F	2
101913-A27	95	18.2	M	1
101913-A28	40	1.4	M	0
103013-B1	80	11.7	F	2
103013-B2	90	17.9	F	1
103013-B3	109	25.6	F	2
103013-B4	108	17.4	M	0
103013-B5	60	3.8	M	1
103013-B6	62	4.7	M	1
103013-B7	59	4	M	0
103013-B8	36	1.1	M	0
103013-B9	97	19.2	M	0
103013-B10	95	16.5	F	0
103013-B11	80	9.2	M	1
103013-B12	36	1.3	M	0
102813-C1	93	14.9	M	0
102813-C2	60	5.2	F	0
102813-C3	89	13.2	M	2
102813-C4	60	4.7	M	0
102813-C5	36	1	M	0
102813-C6	64	5.2	M	0
102813-C7	66	5.8	M	1
102813-C8	75	8.4	M	1
102813-C9	82	11.8	M	1
102813-C10	99	19.4	M	2
102813-C11	101	20.1	M	1
102813-C12	100	21.1	M	0
102813-C13	71	7.6	M	0
102813-C14	86	12.1	M	1
102813-C15	88	13.4	M	1
102813-C16	97	18	F	1
102813-C17	71	7	M	0
102813-C18	73	7.3	M	0
102813-C19	80	9.6	F	0
102813-C20	81	10	M	1
102813-C21	90	15.1	F	0
102813-C22	90	16.2	M	1
102813-C23	104	22.3	M	0
111313-A1	136	40.4	F	2

111313-A2	105	23.1	M	1
111313-A3	96	17.9	F	0
111313-A4	80	9.9	M	0
111313-A5	123	36.5	F	1
111313-A6	70	6.4	M	1
111313-A7	66	5.2	M	0
111313-A8	48	2.3	M	0
111313-A9	98	19.7	M	0
111313-A10	91	15.2	F	0
111313-A11	65	5.2	M	0
111313-A12	58	3.9	M	0
111313-A13	60	4.3	M	0
111313-A14	61	4.5	M	0
111313-A15	55	3.2	M	0
111313-A16	56	3.5	M	0
111313-A17	111	26.9	M	0
111313-A18	60	4.2	M	0
111313-A19	60	4.8	M	0
111313-A20	56	3.5	M	0
111313-A21	109	23.2	M	0
111313-A22	51	2.7	M	0
111313-A23	57	4	M	0
111313-A24	55	3.4	M	0
111313-A25	42	1.6	M	0
111313-A26	39	1.3	M	0
111313-A27	35	0.9	M	0
111713-B1	96	15.9	F	0
111713-B2	77	8.2	F	1
111713-B3	64	5.4	M	0
111713-B4	55	3	M	1
112513-C1	98	19.9	M	1
112513-C2	100	18.6	M	0
112513-C3	89	12.8	M	0
112513-C4	86	11.9	F	1
112513-C5	124	33.9	F	2
112513-C6	79	8.6	F	0
112513-C7	83	10.7	M	1
112513-C8	91	15.4	M	0

APPENDIX C: STOMACH CONTENTS

	090813-A1	090813-A2	090813-A3	090813-A4	090813-A5	090813-A6	090813-A7	090813-A8	090813-A9	090813-A10	090813-A11	090813-A12
Oligochaeta												
Ephemeroptera			3									
Eph Adult												
Heptagenidae												
Beatidae		1				1						
Plecoptera												
Trichoptera		1										
Trichoptera Pupa			1									
Hydropsychidae						1						
Cheuymatopsyche											1	
Diptera												
Diptera Pupa												
Diptera Adult	1				2		1					
Chironomidae			22		9		2	1			1	2
Chironomid Pupa						1						
Simuliidae					1							
Tipulidae												
Lepidoptera			1		1							
Odonata												
Coleoptera												
Psephenidae	1											
Curculionoidae		1		1								
Elmidae												
Hemiptera												
Cicadellidae		1		2								
Gerridae												
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda			1									
Isopoda					1							
Gastropoda												
Ferrissia rivularis											1	
Snail												
Fish	1											
Ant		1										

Spider				
Misc.	1	1	1	2

	090813-A13	090813-A14	090813-A15	090813-A16	090813-A17	090813-A18	090813-A19	090813-A20	090813-A21	090813-A22	090813-A23	090813-A24
Oligochaeta												
Ephemeroptera						1						
Eph Adult						1						
Heptagenidae						2						
Beatidae												
Plecoptera							2					
Trichoptera						1	2	1			2	
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa						1						
Diptera Adult							3			3	2	
Chironomidae						49	1	3		2	1	2
Chironomid Pupa												
Simuliidae						1						
Tipulidae					1							
Lepidoptera								1			1	
Odonata												
Coleoptera												
Psephenidae												
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae		1					6			2	1	
Gerridae												
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda						1						
Isopoda												
Gastropoda												
Ferrissia rivularis						2						
Snail												
Fish												
Ant							1					1
Spider												
Misc.							1					

	090813-A25	090813-A26	090813-A27	090813-A28	090813-A29	090813-A30	090813-A31	090813-A32	090813-A33	090813-A34	090813-A35	091413-B1
Oligochaeta												
Ephemeroptera												
Eph Adult				4								
Heptagenidae												
Beatidae												
Plecoptera												
Trichoptera				2					1			4
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa												
Diptera Adult		1		3			1					21
Chironomidae	1	1	1	1		5	4		1	4	1	17
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera	1											
Odonata												
Coleoptera												
Psephenidae												
Curculionoidae			1									
Elmidae												
Hemiptera												
Cicadellidae		1	1	2			1		1			
Gerridae												
Corixidae		1					1					
Trombidiformes							1					1
Megaloptera												
Decapoda				2								
Isopoda												
Gastropoda												
Ferrissia rivularis		2										
Snail												
Fish												
Ant			2									
Spider												
Misc.	2	1		1					1	1		11

	091413-B2	091413-B3	091413-B4	091413-B5	091413-B6	091413-B7	091413-B8	091413-B9	091413-B10	091413-B11	091413-B12	091413-B13
Oligochaeta												
Ephemeroptera												
Eph Adult												
Heptagenidae						2				1		
Beatidae												
Plecoptera												
Trichoptera	1		2	3	1	1	2		2		1	2
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera								1				
Diptera Pupa												
Diptera Adult	1	1	1		1	1		1		1		4
Chironomidae	3	49		11	1	1	2	3	4	2		4
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera						1				2		
Odonata						3						
Coleoptera							1					
Psephenidae								1				
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae	1		2		1		2	1		2		
Gerridae					1					1		
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda	1		2	1	1							1
Isopoda												
Gastropoda												
Ferrissia rivularis				3	12	1	3	5		1		
Snail			1	2			4					
Fish												
Ant							2					
Spider										1		
Misc.			2			2	4	3	12	1		1

	091413-B14	091413-B15	091413-B16	091413-B17	091413-B18	091413-B19	091413-B20	091413-B21	091413-B22	091413-B23	091413-B24	091413-B25
Oligochaeta												
Ephemeroptera					1							1
Eph Adult												
Heptagenidae					1				3			
Beatidae												
Plecoptera												
Trichoptera	1	3	2		2			2	3	1		2
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera		2										1
Diptera Pupa												
Diptera Adult	1	4	1	2	1	2	1			2		
Chironomidae	11		1	1	11		2	5	2	1		2
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera									2			
Odonata												
Coleoptera												1
Psephenidae		1									1	
Curculionoidae												
Elmidae		1										
Hemiptera												
Cicadellidae		1		2				3		1		2
Gerridae												
Corixidae								1				
Trombidiformes												
Megaloptera												
Decapoda									1		1	
Isopoda												
Gastropoda												
Ferrissia rivularis			3									
Snail								1			1	1
Fish												
Ant		1				3			2	1		
Spider												
Misc.		1		2		1				1		5

	091413-B26	091413-B27	091413-B28	091413-B29	091413-B30	091413-B31	091413-B32	091413-B33	091413-B34	091413-B35	091413-B36	091413-B37
Oligochaeta												
Ephemeroptera												
Eph Adult												
Heptagenidae				2								
Beatidae				1								
Plecoptera												
Trichoptera	2		2				1		1	1	3	
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa											1	
Diptera Adult		4				1	1	2	7		2	4
Chironomidae	2	6	4			50	40	7	10	1	40	6
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera			1									
Odonata		1										
Coleoptera											1	
Psephenidae				7								
Curculionoidae												
Elmidae		1										
Hemiptera												
Cicadellidae			1	3							1	
Gerridae			1	1								
Corixidae		1						1				
Trombidiformes												
Megaloptera												
Decapoda												
Isopoda												
Gastropoda												
Ferrissia rivularis	5	2				1			1	40	4	
Snail												
Fish												
Ant												
Spider				1							1	
Misc.	1	1		3					1		2	

	092913-C1	092913-C2	092913-C3	092913-C4	092913-C5	092913-C6	092913-C7	092913-C8	092913-C9	092913-C10	092913-C11	092913-C12
Oligochaeta												
Ephemeroptera												
Eph Adult												
Heptagenidae								1	1			
Beatidae												
Plecoptera		1										
Trichoptera			1	2	1	3	1					
Trichoptera Pupa												
Hydropsychidae					1							
Cheuymatopsyche												
Diptera												
Diptera Pupa												
Diptera Adult			1		1		4					2
Chironomidae				2			1	1		3		
Chironomid Pupa												
Simuliidae												
Tipulidae				1						1		
Lepidoptera											1	
Odonata												
Coleoptera												
Psephenidae					1							
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae	2						2					1
Gerridae												1
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda		1	1				1		1			
Isopoda												
Gastropoda												
Ferrissia rivularis				1			1			1		
Snail						1						
Fish												
Ant				1								
Spider												
Misc.			1			1	8	1	1			5

	092913-C13	092913-C14	092913-C15	092913-C16	092913-C17	092913-C18	092913-C19	092913-C20	092913-C21	092913-C22	092913-C23	092913-C24
Oligochaeta												
Ephemeroptera						1		1			1	
Eph Adult												
Heptagenidae		1			3	1	1					
Beatidae												
Plecoptera												
Trichoptera		1	1	2			1		2	1		
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa												
Diptera Adult	2			4							1	
Chironomidae	1	1	3	4		1		2				
Chironomid Pupa						1						
Simuliidae												
Tipulidae												
Lepidoptera	1											
Odonata												
Coleoptera	1			1								
Psephenidae												
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae	1		1									
Gerridae	6	3										2
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda		1			1						1	1
Isopoda		1										
Gastropoda												
Ferrissia rivularis		1			2	1		8	1			
Snail									1			
Fish												
Ant	2							1				
Spider												
Misc.	2			1			1			1		

	092913-C25	092913-C26	092913-C27	092913-C28	092913-C29	092913-C30	101913-A1	101913-A2	101913-A3	101913-A4	101913-A5	101913-A6
Oligochaeta												
Ephemeroptera												
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera												
Trichoptera		3	1		3	1	3	1	7			
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa												
Diptera Adult								1				
Chironomidae							2		1			
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera									2			
Odonata												
Coleoptera												
Psephenidae												
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae												
Gerridae												
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda		1										
Isopoda												
Gastropoda												
Ferrissia rivularis			3									
Snail												
Fish												
Ant												
Spider												
Misc.												

	101913-A7	101913-A8	101913-A9	101913-A10	101913-A11	101913-A12	101913-A13	101913-A14	101913-A15	101913-A16	101913-A17	101913-A18
Oligochaeta												
Ephemeroptera												
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera												
Trichoptera							1	1		1		2
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa								1				
Diptera Adult			1					1				1
Chironomidae			5	12		10	20	3		9		1
Chironomid Pupa				1								
Simuliidae												
Tipulidae												
Lepidoptera												1
Odonata												
Coleoptera						2						
Psephenidae												
Curculionoidae												
Elmidae							1					
Hemiptera												
Cicadellidae												1
Gerridae		5		1								
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda		1										
Isopoda												
Gastropoda												
Ferrissia rivularis				4								
Snail				5			1					
Fish												
Ant			1									
Spider												
Misc.			4	1			1					

	101913-A19	101913-A20	101913-A21	101913-A22	101913-A23	101913-A24	101913-A25	101913-A26	101913-A27	101913-A28	103013-B1	103013-B2
Oligochaeta												
Ephemeroptera												
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera												
Trichoptera						2	1					
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa			1									
Diptera Adult	2		1							1		1
Chironomidae			1	1			4			7	1	
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera									1			
Odonata												
Coleoptera												
Psephenidae												
Curculionoidae	1											
Elmidae												
Hemiptera												
Cicadellidae												
Gerridae							2	4			6	
Corixidae										1		
Trombidiformes												
Megaloptera												
Decapoda												1
Isopoda												
Gastropoda												
Ferrissia rivularis								2				
Snail												
Fish												
Ant											1	2
Spider												
Misc.							1					4

	103013-B3	103013-B4	103013-B5	103013-B6	103013-B7	103013-B8	103013-B9	103013-B10	103013-B11	103013-B12	102813-C1	102813-C2
Oligochaeta												
Ephemeroptera			1					1				
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera												
Trichoptera	1	7	2	3	2	3		1	3			
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa												
Diptera Adult	3	1				1						
Chironomidae	1			5	1	3			6	1		
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera						1						
Odonata												
Coleoptera												
Psephenidae												
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae				1	1						1	
Gerridae		2			5			1			9	
Corixidae		1										
Trombidiformes												
Megaloptera												
Decapoda												
Isopoda												
Gastropoda												
Ferrissia rivularis									1		1	1
Snail												
Fish												
Ant	1		2					4				
Spider												
Misc.			1	1				4	2			

	102813-C3	102813-C4	102813-C5	102813-C6	102813-C7	102813-C8	102813-C9	102813-C10	102813-C11	102813-C12	102813-C13	102813-C14
Oligochaeta												
Ephemeroptera										1		
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera												
Trichoptera	1			2			2	2		49	2	1
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa												
Diptera Adult				4		8						4
Chironomidae		2		3		3	3			1	6	
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera												
Odonata												
Coleoptera												
Psephenidae												
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae				2								3
Gerridae	4									4	1	2
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda												
Isopoda				2								
Gastropoda												
Ferrissia rivularis			1									3
Snail												
Fish												
Ant								1				1
Spider				1								
Misc.		1				12		1		1		5

	102813-C15	102813-C16	102813-C17	102813-C18	102813-C19	102813-C20	102813-C21	102813-C22	102813-C23	111313-A1	111313-A2	111313-A3
Oligochaeta												
Ephemeroptera												
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera												
Trichoptera				3		4	3		1		4	
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa												
Diptera Adult	2											1
Chironomidae		3		1		3			1			
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera												
Odonata												
Coleoptera												
Psephenidae												
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae						3			2			3
Gerridae			1					1				
Corixidae					1							
Trombidiformes												
Megaloptera												
Decapoda		1										
Isopoda												
Gastropoda												
Ferrissia rivularis					1			1				
Snail												
Fish												
Ant			1									
Spider												
Misc.								1	2			

	111313-A4	111313-A5	111313-A6	111313-A7	111313-A8	111313-A9	111313-A10	111313-A11	111313-A12	111313-A13	111313-A14	111313-A15
Oligochaeta												
Ephemeroptera											1	
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera												
Trichoptera					3						1	
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa												
Diptera Adult												
Chironomidae	1	4			1	1	1				1	
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera											1	
Odonata												
Coleoptera												
Psephenidae												
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae												
Gerridae									1			
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda												
Isopoda										1		
Gastropoda												
Ferrissia rivularis												
Snail												
Fish												
Ant												
Spider												
Misc.												

	111313-A16	111313-A17	111313-A18	111313-A19	111313-A20	111313-A21	111313-A22	111313-A23	111313-A24	111313-A25	111313-A26	111313-A27
Oligochaeta												
Ephemeroptera												
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera												
Trichoptera						1			2			
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa												
Diptera Adult					1	2	1					
Chironomidae							3		5			
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera												
Odonata												
Coleoptera												
Psephenidae												
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae		1										
Gerridae												
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda												
Isopoda												
Gastropoda												
Ferrissia rivularis												
Snail												
Fish												
Ant						1						
Spider												
Misc.				1		1						

	111713-B1	111713-B2	111713-B3	111713-B4	112513-C1	112513-C2	112513-C3	112513-C4	112513-C5	112513-C6	112513-C7	112513-C8
Oligochaeta												
Ephemeroptera	1	1			1							
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera						1						
Trichoptera		3	4	2	2		6					4
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa												
Diptera Adult	11					4	4					
Chironomidae	13	5	8	1	1							
Chironomid Pupa						1			1			
Simuliidae												
Tipulidae												
Lepidoptera	1			2								
Odonata					1	1	1					
Coleoptera								1				
Psephenidae												
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae							1					
Gerridae						1						2
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda												
Isopoda												
Gastropoda												
Ferrissia rivularis								1				
Snail												
Fish												
Ant	1							2				
Spider												
Misc.	4					4	4	2				2

	032414-A1	032414-A2	032414-A3	032414-A4	032414-A5	032414-A6	032414-A7	032414-A8	032414-A9	032414-A10	032414-A11	032414-A12
Oligochaeta						Y	Y					
Ephemeroptera	1	12	1					2				1
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera												
Trichoptera	2	5	4		1	1		1	1		1	1
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa												
Diptera Adult												
Chironomidae		7	32	1		2	1	10	1		6	
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera		1										
Odonata												
Coleoptera												
Psephenidae												
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae												
Gerridae												
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda		2				3			1			
Isopoda												
Gastropoda												
Ferrissia rivularis												
Snail												
Fish												
Ant												
Spider												
Misc.												

	032414-A13	032414-A14	032414-A15	032414-A16	032414-A17	032414-A18	032414-A19	032414-A20	032414-A21	032414-A22	032414-A23	032414-A24
Oligochaeta	Y	Y		Y		Y	Y	Y	Y	Y	Y	Y
Ephemeroptera			1					4			1	11
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera												
Trichoptera			5	2				1		2		6
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa												
Diptera Adult												
Chironomidae			2		1	7		2	10	2	1	5
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera												
Odonata												
Coleoptera												
Psephenidae												
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae												
Gerridae												
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda				1								
Isopoda												
Gastropoda												
Ferrissia rivularis												
Snail												
Fish												
Ant												
Spider												
Misc.			1									

	032414-A25	032414-A26	032114-B1	032114-B2	032214-C1	041814-A1	041814-A2	041814-A3	042414-B1	042414-B2	042414-B3	042414-B4
Oligochaeta	Y	Y	Y	Y	Y	Y	Y	Y			Y	
Ephemeroptera	1	1			2	2	4		1	1	2	2
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera												
Trichoptera	1	3	6	6					4	1		
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera				2								
Diptera Pupa	2											
Diptera Adult												
Chironomidae	32	22		1					5	3	1	
Chironomid Pupa												
Simuliidae												
Tipulidae												
Lepidoptera				1								
Odonata												
Coleoptera												
Psephenidae												
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae												
Gerridae												
Corixidae												
Trombidiformes												
Megaloptera												
Decapoda												
Isopoda												
Gastropoda												
Ferrissia rivularis												
Snail												
Fish												
Ant												
Spider												
Misc.				1								

	042414-B5	041714-C1	041714-C2	041714-C3	041714-C4	050414-A1	050414-A2	050414-A3	052114-C1	052114-C2	052114-C3	062214-A1
Oligochaeta		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ephemeroptera	50	7	2	6	7	40	2		5	15	7	
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera											1	
Trichoptera	1	2		1		3			6	1	1	7
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa												
Diptera Adult							2				2	
Chironomidae					1	1	2		4		1	11
Chironomid Pupa												
Simuliidae												
Tipulidae									1			
Lepidoptera												
Odonata												
Coleoptera												
Psephenidae												1
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae												
Gerridae				1								
Corixidae												
Trombidiformes												
Megaloptera												1
Decapoda												
Isopoda												
Gastropoda												
Ferrissia rivularis											1	
Snail												
Fish												
Ant												
Spider												
Misc.		1										1

	062214-A2	062214-A3	062214-A4	062214-A5	062214-A6	062214-A7	062214-A8	062214-A9	062214-A10	062214-A11	062314-B1	062314-B2
Oligochaeta	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y
Ephemeroptera		1										
Eph Adult												
Heptagenidae												
Beatidae												
Plecoptera												
Trichoptera		3		1			1				4	5
Trichoptera Pupa												
Hydropsychidae												
Cheuymatopsyche												
Diptera												
Diptera Pupa				1								
Diptera Adult												
Chironomidae		11	11	19	21	1	1		1	14	35	47
Chironomid Pupa												
Simuliidae												
Tipulidae	1											
Lepidoptera												
Odonata												
Coleoptera								4				
Psephenidae												
Curculionoidae												
Elmidae												
Hemiptera												
Cicadellidae												
Gerridae												
Corixidae												
Trombidiformes			1									
Megaloptera								1				
Decapoda					1							
Isopoda												
Gastropoda												
Ferrissia rivularis												
Snail												
Fish												
Ant					1							1
Spider												
Misc.			2	1	1							1

	062314-B3	062314-B4	062314-B5	062314-B6	062414-C1	062414-C2	062414-C3
Oligochaeta	Y	Y	Y	Y	Y	Y	Y
Ephemeroptera						1	
Eph Adult							
Heptagenidae							
Beatidae							
Plecoptera					1		
Trichoptera	4	2	1	1		2	
Trichoptera Pupa							
Hydropsychidae							
Cheuymatopsyche							
Diptera							
Diptera Pupa			1	1			
Diptera Adult					5		
Chironomidae	66	83	2	57	3	13	
Chironomid Pupa							
Simuliidae							
Tipulidae			1		1	2	2
Lepidoptera			1		1		
Odonata							
Coleoptera						1	
Psephenidae				1			
Curculionoidae							
Elmidae							
Hemiptera							
Cicadellidae							
Gerridae					1		
Corixidae							
Trombidiformes						1	
Megaloptera							
Decapoda	2						
Isopoda							
Gastropoda							
Ferrissia rivularis					1		
Snail	1						
Fish							
Ant	2						1
Spider							
Misc.	1	1			1		